

JOURNAL OF THE
BOSTON SOCIETY
OF
CIVIL ENGINEERS



NOVEMBER - 1933

VOLUME XX

NUMBER 9

BOSTON SOCIETY OF CIVIL ENGINEERS

OFFICERS, 1933-1934

PRESIDENT

ARTHUR W. DEAN

VICE-PRESIDENTS

JOHN B. BABCOCK, 3d
(Term expires March, 1934)

HAROLD K. BARROWS
(Term expires March, 1935)

SECRETARY

EVERETT N. HUTCHINS

TREASURER

KARL R. KENNISON

DIRECTORS

JOHN C. MOSES
EDWARD WRIGHT
(Term expires March, 1934)

HARRY P. BURDEN
ARTHUR C. EATON
(Term expires March, 1935)

PAST PRESIDENTS

LEWIS E. MOORE

HARRY E. SAWTELL

RALPH W. HORNE

SANITARY SECTION

GEORGE G. BOGREN, Chairman

FRANK L. FLOOD, Clerk

DESIGNERS SECTION

FREDERIC N. WEAVER, Chairman

HENRY BRASK, Clerk

HIGHWAY SECTION

ALBERT E. KLEINERT, Jr., Chairman

ARTHUR P. RICE, Clerk

NORTHEASTERN UNIVERSITY SECTION

ANTHONY TEDESCO, Chairman

A. BRUCE SCHOW, Clerk

Librarian — EDWARD S. AVERELL

Editor — EVERETT N. HUTCHINS

715 Tremont Temple, Boston

JOURNAL OF THE BOSTON SOCIETY OF CIVIL ENGINEERS

Volume XX

NOVEMBER, 1933

Number 9

CONTENTS

PAPERS AND DISCUSSIONS

PAGE

- Protection of Hartford South Meadows at Hartford,
Connecticut. A Symposium. *Roscoe N. Clark,*
W. S. Brewer, William A. D. Wurts, Frederic H. Fay,
Prof. Glennon Gilboy, Prof. Kenneth C. Reynolds . 187
- Discussion. *Harrison P. Eddy* 232

OF GENERAL INTEREST

- Proceedings of the Society 233

Published Monthly, except July and August, by the Society
715 Tremont Temple, Boston, Massachusetts

Subscription Price, \$4.00 a Year (10 Copies)
50 Cents a Copy

COMING MEETINGS

SOCIETY—WEDNESDAY, DECEMBER 20

"Steel in Residence Construction," by F. T. Llewellyn, Assistant to the President of the United States Steel Corporation.

6.00 P.M. Buffet Supper. 7.00 P.M. Meeting, Engineers Club.

SANITARY SECTION—WEDNESDAY, DECEMBER 6

6.00 P.M. Society Rooms, 715 Tremont Temple, Boston.

"Measurement of Sewage Flow," by Karl R. Kennison, Metropolitan District Water Supply Commission.

Dinner at 6.00 P.M. at Patten's Restaurant.

DESIGNERS SECTION—WEDNESDAY, DECEMBER 13

6.00 P.M. Society Rooms, 715 Tremont Temple, Boston.

"Structural Features of Theater Design," by Mark Linenthal, Engineer.

Copyright, 1933, by the Boston Society of Civil Engineers.
Entered as second-class matter, January 15, 1914, at the Post Office
at Boston, Mass., under Act of August 24, 1912.

Acceptance for mailing at special rate of postage provided for in
Section 1103, Act of October 3, 1917, authorized on July 16, 1918.

*The Society is not responsible for any statement made or opinion
expressed in its publications.*

BOSTON
WRIGHT & POTTER PRINTING COMPANY
32 DERNE STREET

JOURNAL OF THE BOSTON SOCIETY OF CIVIL ENGINEERS

Volume XX

NOVEMBER, 1933

Number 9

PROTECTION OF HARTFORD SOUTH MEADOWS AT HARTFORD, CONNECTICUT

A Symposium

(Presented at a meeting of the Boston Society of Civil Engineers held on January 25, 1933)

THE PROJECT IN GENERAL

BY ROSCOE N. CLARK *

LOCATION

IMAGINE a plane, roughly triangular in shape, with its length about three miles and its width about one mile, having a fairly uniform surface sloping gradually from an elevation of 22 at the apex to an elevation of 6 or 8 at the base.

Further, imagine this plane, which extends in a northerly and southerly direction, to be bounded on one of its long sides by a river and on the other long side by a slope of land rising to a considerable height above the average elevation of the plane itself, and you have a picture of the South Meadows in Hartford.

The Connecticut River, which extends along the easterly side of the triangle forming the meadows, is at this point about 1,200 feet in width, with flood variations in the elevation of its surface ranging from 0 to nearly plus 30, referring to the datum established by the engineers of the United States War Department. This datum differs slightly from that used by the city of Hartford. Zero on the government datum is

* City Engineer, Hartford, Connecticut.

plus 1.57 on the city datum. Inasmuch as the city's system of bench marks was used throughout the construction of this work, all elevations mentioned in these papers will be referred to that datum.

HISTORICAL

Along the upper right-hand side of these meadows flows a small tributary of the Connecticut River, known as the Park River, about 100 feet in width. This stream enters the Connecticut River about one-quarter of a mile south from the apex of the triangle forming the meadows, as before described. When the band of Pilgrims under Thomas Hooker arrived in 1635 at the site of what was destined to become the city of Hartford they found a small settlement of Dutch on the banks of this small tributary, and at the upper end of the meadows here they had built a log fort known as the "Huyshope" or "House of Hope,"—the name of which has been handed down and carried along through the history of Hartford as the name of one of its streets in the vicinity. During the early colonial days these meadows were the camping ground of Indian tribes of the vicinity, and after these had passed from the picture the meadows gradually became used by the settlers as pasture lands and hay lands. On the higher parts, even as late as the recent operations leading to the construction of the dike, vegetable gardens were cultivated, but for the most part the only return from these meadows was the annual hay crop.

About 1860 Colonel Samuel Colt, of revolver fame, established on the meadows a plant for the manufacture of firearms. This plant was established near the apex of the triangular-shaped meadows, and in order to protect it and the adjoining lands, of which he was the most extensive proprietor, Colonel Colt built a dike cutting off the apex of this triangle. This dike extended along the Park River, thence a short distance below its mouth along the bank of the Connecticut River, and thence turning substantially at right angles and extending to the highland bordering the meadows along the westerly side. The two legs of the angle thus formed by Colonel Colt's dike were about 3,500 feet long, enclosing about one-half square mile of the upper end of the meadows. A few years previous to the construction of this dike, namely, in 1854, the Connecticut River experienced the highest recorded flood in its history, when the water rose to an elevation of 31.4 city datum. Presumably the experience of this flood spurred Colonel Colt on to greater efforts to the protection of his investments at this location.

Many years then elapsed before any considerable attention was given to reclamation of these meadows.

IMPETUS TO PROJECT

No official consideration was given to the reclamation of these meadows until in 1917, when the Commission on the City Plan submitted to the Court of Common Council a report recommending that steps be taken toward such reclamation, and indicating how it might be undertaken. The matter was again inactive for four years, until, at the instance of the Hartford Chamber of Commerce, the General Assembly of the State was petitioned to amend the charter of the city to provide for the establishment of a commission to undertake the reclamation of these meadows, as well as of a similar meadow tract lying along the Connecticut River north of the city proper. This commission was duly established and its members appointed in the same year (1921). Fay, Spofford & Thorndike, Consulting Engineers, of Boston, were engaged by that Commission to make a preliminary study of the situation, with recommendations as to the feasibility of the project. In the meantime Hartford had become air-minded, and an Aviation Commission was formed which selected a part of these meadows as its landing field.

EXTREME FLOODS

In November, 1927, the Connecticut River again went on a rampage, and rose to a height of 30.6, which had been exceeded only once in recorded history, namely, in 1854, as before mentioned. The new aviation field was covered 10 feet deep with water, and the hangars and temporary buildings which had been erected were flooded and in some instances wrecked. This happening was possibly an added spur to the need of further reclamation proceedings, and in 1928 an appropriation was made for a detailed survey, with Fay, Spofford & Thorndike again retained to make definite recommendations for a dike and estimates of cost. This report was made and submitted to the Meadows Development Commission, which immediately asked for an appropriation sufficient to carry out the work. At this point a controversy arose between the Development Commission and the city government. At the 1929 session of the legislature the Meadows Development Commission was abolished and the Court of Common Council turned over the work of carrying on the reclamation program to the Board of Street Commissioners, which corresponds to the usual board of public works in most New England cities.

BOARD OF STREET COMMISSIONERS

The Board of Street Commissioners referred the matter to me as their technical adviser, and steps were immediately taken to get the work in shape for letting a contract. Messrs. Fay, Spofford & Thorndike were further retained as consulting engineers by the Board of Street Commissioners, upon my recommendations.

The formal proceedings through the Board of Aldermen for the layout and assessment were passed in February, 1930. The contracts for clearing and grubbing and steel sheet pile cut-off were let in March, 1930, and the contract for the dike proper in August of that year.

DEVELOPMENT OF THE HARTFORD SOUTH MEADOWS

BY FREDERIC H. FAY *

SITE

LOCATED in the extreme southeast corner of the city of Hartford, Connecticut, bordering the Connecticut River, lie the Hartford South Meadows, a low area of meadow land approximately two square miles in extent. This entire tract is below extreme flood heights of the river; most of the area was formerly covered by water at times of even moderate floods, which occur nearly every year and often several times in the same year. The highest land is found in the northerly portion, while valleys between ridges leading to the southwesterly corner of the tract were at such low level that they were permanently flooded. These swamp areas constituted health nuisances and fertile breeding grounds for mosquitoes.

PRELIMINARY INVESTIGATION

The reclamation of the South Meadows was actively considered in 1921. In that year the speaker's firm made an economic and industrial survey for the Hartford Meadows Development Commission, to determine an advantageous utilization of the tract, primarily for industrial and water-front purposes.

All portions of the relatively small city area, other than the extensive South and North Meadows along the river, have become quite

* Of Fay, Spofford & Thorndike, Consulting Engineers, 44 School Street, Boston, Mass.

fully developed. The 1921 investigation demonstrated that the South Meadows, if reclaimed, would be an excellent site for industrial growth. Of the 1,200 acres of the South Meadows it was found that only a small portion, along the Middletown Branch of the New Haven Railroad, was needed for the reasonable growth of industries of this character, and the recommendation at that time was that the larger part of the area be devoted to residential development.

For some time after the 1921 investigation nothing further was done toward the reclamation of the South Meadows.

ESTABLISHMENT OF BRAINARD FIELD

Several years later Brainard flying field was located in the northerly or higher part of the meadows, and this has now become one of the important airports of the country.

In the early part of November, 1927, the Connecticut River rose to a height of 30.6 feet, Hartford city datum, and the entire meadows, including the aviation field, were covered with water. This flooding of the airport brought home to the citizens of Hartford the immediate necessity of protecting the airport from floods if it were to be of the maximum use. There was also realized the advantage of having near the aviation field lands for use of the various industries connected with aviation.

With the meadows fully protected against floods of the river, the lower areas filled and proper provisions made for drainage, both of these conditions would be realized.

PROTECTION OF HARTFORD SOUTH MEADOWS

In 1928 the speaker's firm was again engaged by the Hartford Meadows Development Commission to make recommendations for the protection of the meadows and to prepare preliminary plans and estimates of cost of structures necessary to accomplish this purpose.

A topographical plan of the South Meadows area was compiled and a survey of the area adjoining the river and the Wethersfield town line was made. At the same time numerous wash borings were taken in the area where it was expected to locate the dike, and also in the river and at various points throughout the entire South Meadows tract. These borings were made to determine foundation conditions for the dike, the character of material available for dike construction, and the general geological conditions underlying the entire meadows. Dr.

Terzaghi, formerly Professor of Soil Mechanics at the Massachusetts Institute of Technology, was engaged as consultant at this time. Many of the borings were made under his direction and various samples of soil were analyzed. Later, this work was carried on by Professor Glennon Gilboy, successor to Dr. Terzaghi. Dr. Gilboy will tell you of this work.

DIKE

Reclamation of the South Meadows area by filling to a level above extreme flood height was impractical because of the prohibitive cost. The practical and economical method of reclamation was by building a dike or levee from the high land near Warwarme Avenue on the north, southerly for two miles along the river bank, and thence westerly for an additional mile along the Wethersfield town line to high land on Wethersfield Avenue. Although the reclaimed meadows will remain permanently below maximum flood heights, only their lower portions require filling to be usable, and these filled to relatively shallow depth. With the dike completed, the entire area can safely be built upon without danger from floods.

The location of the dike was determined: first, to provide the maximum usable area inside the dike; second, to provide an economical location with reference to obtaining and placing materials for its construction; and third, to provide a uniform flood channel for the river. The top of the dike was designed to be approximately 4 feet above maximum flood.

MATERIALS FOR DIKE CONSTRUCTION

Material most readily available for construction of the dike was the coarse sand of the river bed. This coarse sand stratum extends from the river in a nearly horizontal plane beneath the South Meadows area. Overlying this coarse stratum is a surface layer of varying thickness of fine, silty or compact sand. This fine, silty sand was found to be but slightly permeable, and, when properly placed and compacted, to be excellent material for a dike. The coarse river sand, on the other hand, is about seventy-five times more permeable, and water will flow through it so freely that it would not be possible to build a dike of this material alone without excessive leakage.

As a result of Dr. Terzaghi's investigations, the construction of a sheet pile cut-off beneath the dike was found necessary, since without this cut-off the flow of water through the coarse underlying sand stratum would subject the meadows area, after the dike was completed, to

danger of boils, because of the comparatively thin layer of the impermeable silty sand material overlying the coarse sand. This sheet pile cut-off extends beneath the dike for its entire length, and was driven through the coarse sand into compact clay beneath.

Three types of dike were considered:

1. River sand dike with flat slopes.
2. River sand dike with concrete protection on steep river slope.
3. Silty sand dike.

1. River Sand Dike with Flat Slopes

A dike could have been built by hydraulic methods, using the coarse sand from the river bed, but the most economical section would have required slopes approximately 10 horizontal to 1 vertical. This dike with these flat slopes would have been stable, but unless the river slope were blanketed with some fairly water-tight material the seepage at flood stages of the river would have been excessive.

2. River Sand Dike with Concrete Protection on Steep River Slope

This section of dike had a river slope of 2 horizontal to 1 vertical, and a land slope of 5 horizontal to 1 vertical, with a width of crest at elevation 35 of 15 feet. It was intended to construct this dike by hydraulic methods, using low retaining dikes or baffles to help retain the steep side slopes during construction. The river slope could not be built without a material amount of trimming. It would have been necessary to protect the river slope of this dike from erosion and to form an impervious blanket, which would cut down seepage through it. It was proposed to do this by facing the river slope with concrete.

3. Silty Sand Dike

The section of dike to be constructed of the fine, silty sand had a slope on the river side down to maximum flood plane of 2 horizontal to 1 vertical, and from this elevation to ground surface of 3 horizontal to 1 vertical. The slope on the land side varied from 2 to $2\frac{1}{4}$ horizontal to 1 vertical. It was proposed to protect both slopes of this dike by grassing. This section, with a top width of 15 feet, was somewhat larger than necessary to provide stability or to insure a reasonable minimum amount of seepage, but because of the more or less unstable character of the material of which the dike was built, and even with the grass protection, it was still thought well worth while to provide a section of more than adequate strength.

DIKE RECOMMENDED IN 1928

Based on the study of these three sections the following recommendations were made:

First, to construct the dike along the river with the river sand and protect it by concrete facing on the river side. This type of dike would give ample protection against river currents and all material for its construction would be taken from the river. It was proposed to construct a silty sand dike along the major portion of the southerly city line. Here, because of the absence of strong currents in Wethersfield Cove, concrete facing would not be required to protect the outer slope against erosion if these were seeded.

Second, there was ample silty sand material immediately available for its construction.

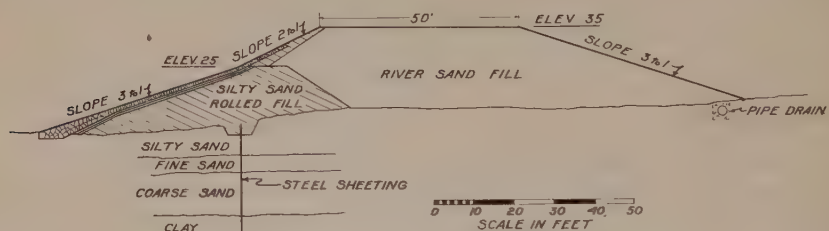


FIG. 1. — TYPICAL CROSS SECTION OF DIKE ALONG CONNECTICUT RIVER

WELLS ALONG THE NORTHERN BORDER OF THE PROPERTY

Dr. Terzaghi's investigation showed that there was a possibility of danger from water flowing from the river beneath the areas northerly of the South Meadows area, but that this danger would be obviated if a series of wells were provided as a cut-off. The water from these wells is to be led through drainage ditches to the southwesterly corner of the meadows area. Here a pumping station has been constructed to take care of the natural drainage of the meadows area, together with any seepage that might come through the dike and from the wells along the northern border. Under ordinary stages of the river no pumping will be required, an outlet being provided by conduits through the dike. Only when the river level is above a predetermined stage will pumping be necessary.

EFFECT OF DIKE ON FLOOD FLOW OF THE CONNECTICUT RIVER

It was determined by studies of the existing data that the dike will have no appreciable effect on the big flood heights by narrowing the width of the channel through which flood waters must pass in the vicinity of South Meadows. There will be a slight effect on the height of floods opposite Hartford itself, but, even under flood conditions similar to those of the 1927 flood, the flood level at the northerly end of the meadows area will be raised less than $3\frac{1}{2}$ inches, and this will decrease rapidly in going up river from this point.

SUBSEQUENT PROCEDURE

The Hartford Meadows Development Commission accepted the 1928 report with its recommendations, and asked for money to carry out the project. The city, however, decided to do the work under the direction of the Street Commissioners. The Hartford South Meadows Development Commission was abolished and the work turned over to the Street Commissioners under the direction of Mr. Roscoe N. Clark, City Engineer, who has already told you something about the project. The speaker's firm served as consultants to Mr. Clark during the carrying out of the undertaking. Under Mr. Clark's direction certain changes were made in the design of the dike. First, the city desired to provide a top width of dike of 50 feet, so that it might be used for a possible future riverside boulevard. With this greatly increased section of dike it was decided to omit the concrete facing and to substitute in its stead a minimum section of silty sand dike, using the river sand as backing, the river slope of the silty sand portion of the structure being protected with riprap and with stone paving.

In order to determine the amount of seepage which could be expected through a dike of this section, also the suitability of the slopes of the dike composed of river sand and of silty sand, arrangements were made for tests at the Massachusetts Institute of Technology, Hydraulic Laboratory, under the direction of Professor K. C. Reynolds, of a dike section on a small scale. Professor Reynolds will give you the results of these studies and show pictures of the tests.

THE SOUTH MEADOWS DIKE

BY WILLARD S. BREWER*

THE construction of the South Meadows dike and the necessary drainage works were all done by contract, with the exception of a small amount of land clearing done by the city's own forces. The preliminary legal proceedings — the layout and the assessment of damages and benefits — were completed in February, 1930, and it was then possible to plan a construction program. As periods of high water in the Connecticut River would be a controlling factor, and as it was realized that the work would take the larger part of two years, it was decided that the project should be completed during the winter of 1931-32 so as to be prepared for the spring freshet of 1932.

The first two contracts — one for the clearing and grubbing of the dike area and one for the sheet pile cut-off — were let in March, 1930, and the third, for the dike itself, was let in August of that year. The contract for the pumping station equipment was given out in December, 1930, and another for the station building with the conduits through the dike in June, 1931.

The actual progress on the dike was such that it was substantially completed before the high water of April, 1932, which came to the 22-foot level. At that time some minor trimming of slopes on the inside remained to be done, and work was in progress on the seeding. At the pumping station the pumps were ready to run the latter part of January, so that everything was ready for the first high water. A brief account of various operations in the dike construction follows.

CLEARING AND GRUBBING

This work occupied only a few months in the early summer of 1930. The dike location was largely grown to brush and weeds, with a small wooded area. Tree stumps and roots were removed by a gas-powered shovel of the type used in cellar excavation.

SHEET PILE CUT-OFF

The sheet pile cut-off extends the entire length of the dike, a distance of a little more than 15,000 feet. It consists of steel piling $\frac{3}{8}$ inch thick, Bethlehem section AP-16, weighing 29.3 pounds per foot of

* Division Engineer, Department of Engineering, City Hall, Hartford.

piling and 22 pounds per square foot of wall in place. It was driven by two steam hammers working in fixed leads on a traveler running on rails at one side of the line of sheeting, the near rail being 2 feet from the sheeting line. This traveler, 20 feet wide, 40 feet long and of a height of 56 feet above the rail, had a derrick at one forward corner, the one farthest from the rail, which picked all piling from the ground and placed it in position for driving. The piling was shipped from the mill in interlocked pairs, and was handled and driven in this manner. The leads were placed 5 feet 4 inches apart, center to center, equal to the width of two pairs of piling or four sheets. The hammers were

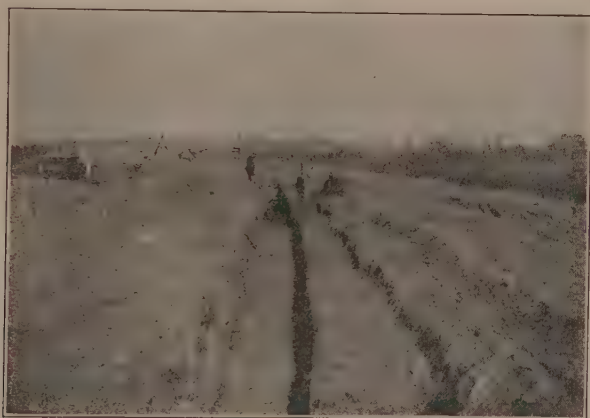


FIG. 2. — CUT-OFF TRENCH

Looking northerly along the river dike, showing cut-off trench and steel sheet piling

offset, thus allowing the traveler to move back and forth at all times without being interfered with by the sheeting already driven.

For the first half mile the top of the sheeting in its driven position was from 1 foot to 12 feet below the ground surface, and the driving here was so hard that an additional small rig was built to carry one hammer, and this was used to do the driving below the ground surface. With this exception the large traveler did all the work.

The first piling was put down on May 7 and the last on October 22, with an elapsed time of 145 days, which means an average progress of 104 feet of cut-off wall every day. The best single day's work was 300 feet. A contributing factor in the speed with which this work was done was the very dry weather throughout the season.

The total weight of steel in this cut-off is about 6,000 tons — all

rolled at the Lackawanna plant of the Bethlehem Steel Company. It is interesting to note that although a small portion at the beginning was shipped by rail, the larger part came by canal boat through the New York Barge Canal, down the Hudson, through Long Island Sound and up the Connecticut River.

DIKE CONSTRUCTION

For its northerly 2,400 feet the dike is located about 600 feet from the river, so as to be in back of the steam-power station of the Hartford Electric Light Company. The section for this length has a top width of 15 feet, with slopes of 2 to 1, and it was built entirely of the silty sand of the meadows. With the exception of this 2,400 feet the dike is composed of a silty sand embankment on the outside to provide watertightness, and a backing of river sand, having a top width of 50 feet. From the river back to the high ground at Wethersfield Avenue the section is the same with these exceptions: the stone slope protection is omitted, the slopes made flatter (3 to 1 above elev. 25; 4 to 1, elev. 25 to elev. 15; and 5 to 1 below elev. 15) and the entire slope seeded.

In September, 1930, work was begun on the silty sand embankment at the northerly end of this 50-foot-wide section and continued southerly until December 1, when a length of one mile had been completed (top at elev. 25). During the winter the stone slope protection on the outside was placed. The spring freshet in 1931 reached only to a height of 18.5 feet, so that it flooded only the southerly portion of the meadows and not the higher northerly portions. No damage was done to that part of the dike which had been built. While the river was high, the northerly 2,400 feet of dike, located back from the river on ground above elev. 20, was built. In June work was resumed on the lower portions, and all silty sand embankment was completed in November, 1931.

The preparation of the ground surface under the silty sand dike consisted in general of scraping off weeds, debris or grass with a bulldozer and then pulling a large disc harrow lengthwise of the dike. This harrow had discs 22 inches in diameter, and it thoroughly cut the surface to a depth of 8 to 10 inches. In the swampy area at the southern end of the meadow the top soil was stripped with a drag line.

CUT-OFF TRENCH

Along the river the ground on which the dike is built is somewhat stratified, silt and fine sand appearing in layers. To prevent river water from working through these sand layers, then over the steel

sheeting and continuing along the sand layer inside the sheeting, a cut-off trench was dug along the line of piling. It had a bottom width of 6 feet, centered on the piling, and extended to a depth of from 2 to 4 feet below the top of the sheeting. In some places the excavated material was put back, and in other places, where the material was too sandy, the trench was filled with material from borrow pits. The refill was compacted at first with hand tampers, but later with power tampers. This work broke up the stratification existing in the original ground.

SILTY SAND EMBANKMENT

The silty sand portion of the dike embankment was built with material from borrow pits in the meadow. For that portion of the dike along the river, and also for a short length east of the railroad, material was excavated by gas-powered shovels and transported to the dike by 5-yard trucks. The shortest haul was about 500 feet and the longest about $1\frac{1}{2}$ miles, while the number of trucks used varied from four to a maximum of thirteen. Trains of steel bottom-dump wagons were used on some of the short-haul work.

The spreading and rolling was accomplished by two caterpillar-sixty tractors, one pulling a Slate scraper roller of 5-yard capacity, and the other equipped with a LaPlant-Choate hydraulic bulldozer. The trucks, of course, accomplished considerable in the way of compacting the materials throughout a large part of the work as they were brought in loaded over the completed portion, then dumped and sent back over the meadow roads. Then, too, the filling was kept spread out over a length of 500 to 1,000 feet, so there was a great deal of travel over the embankment as it was being brought up.

For the southerly embankment, along the city line, from the river to near the railroad, it was desired to use largely the material from the outside of the dike and immediately adjacent to it. As this material had more moisture in it than the material inside the dike on higher ground, and, further, as experience had shown that it was not feasible to roll it, drag-line machines were used to place it directly in the embankment without the use of wagons or trucks. In general, the top 3 to 5 feet of material was used, beginning at a line 40 feet away from the outside toe of the dike and extending out from 150 to 200 feet. These machines started at the outer limit, and by successive throws the material was worked over into the dike. Two machines, one with a 50-foot boom and one with a 60-foot boom, were used. Each was equipped with a unit electric light outfit, so that the work could be carried on at

night as well as during the day. Three 8-hour shifts were used at first, and later two 10-hour shifts.

The total amount of material in the silty sand embankment is about 325,000 cubic yards.

To insure a control of the material used and to measure its compactness after being placed in the dike, numerous soil tests were made during the construction of this silty sand embankment. These tests were of two types, as follows:

First, a series of tests to determine the permeability of material which it was proposed to use in the embankment. These tests served as a control of the character of the material, preventing the extension of borrow pits into unsuitable material.

Second, a series of tests to determine the effectiveness of the compacting operation in the dike itself. These were on samples taken from the embankment as the work progressed and the tests determined the voids ratio, *i.e.*, the ratio of the volume of voids to the volume of grains.

In the rolled embankment the voids ratio ranged from .64 to 1.18, with an average of .76. It is interesting to note that tests made on undisturbed samples taken at borrow-pit locations before excavation gave voids ratio of about 1.0, so it will be seen that the material in the rolled dike is much more compact than the same material in its original state.

Only a few tests were made on the voids ratio of material placed by the drag lines. These averaged 1.14. This material was very wet when placed, as most of these borrow pits were excavated to below the ground-water level. However, the natural settlement brought about by the weight of additional material as the embankment was brought up, coupled with the drying out of the material, must have reduced the voids ratio to a much lower figure.

RIVER SAND EMBANKMENT

About three-quarters of the dike section is composed of river sand, and this material was pumped in from the river by a hydraulic dredge through a 20-inch discharge line. The dredge worked twenty-four hours a day, using three shifts of eight hours each, and the full complement was about 45 men. The preliminary plan of discharging the sand and water, proposed by the contractor, called for two pipes, one near each side of the dike (considering its top), but the work was begun with only one pipe, and this method was followed for the entire length of the dike. This discharge pipe ran parallel with the dike and was located about

15 feet inside of the dike center line, and at the elevation of the finished top. The approach line rested on the sand already deposited, the discharge end being carried about 50 feet ahead of the sand on timber supports. An opening in the bottom of the pipe near the beginning of this supported section allowed a large part of the sand and a little water to drop here, while the remainder was discharged from the end of the pipe.

The silty sand embankment acted as a barrier on the river side, thus forcing the dredge water to run along the dike location until an outlet was reached. In addition, a crane with a clamshell bucket,

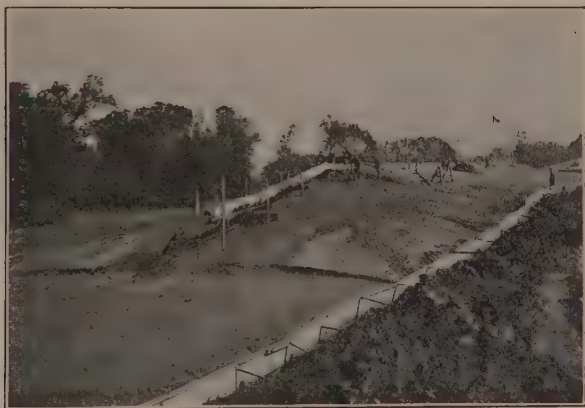


FIG. 3. — SOUTHERLY DIKE

Looking easterly along the southerly dike, showing the placing of river sand back of the silty sand and method of protecting the latter from the dredged material

working on top of the silty sand dike, piled sand against its inside face to a height of 6 to 8 feet above the top, so as to protect the silty sand dike from wash and also to prevent the sand and water working over the top of the silty sand dike. For the embankment along the river the outlet for the dredge water was at its southerly end. Later the outlet was shifted to low places farther west, and finally to the conduits through the pumping station and dike. The slope of the sand, as deposited by the dredge water as it ran off, was, of course, rather flat, being about 5 to 1 at the top and getting flatter as the base of the fill was approached. Near the bottom a slope of 20 to 1 was quite usual. It was necessary, of course, to pull the material in this flat base back into the dike to

produce the section called for. A drag-line machine was used for this operation.

The pumping was begun in June, 1931, and completed in November. In five months 980,000 cubic yards of sand had been pumped into 12,700 linear feet of dike, and in addition several borrow pits and one low area had been filled with sand, the total amount being about 1,133,000 cubic yards.

SLOPE PROTECTION

For a distance of 8,000 feet along the Connecticut River the outside slope was given a protection consisting of: (1) along the toe of the dike,

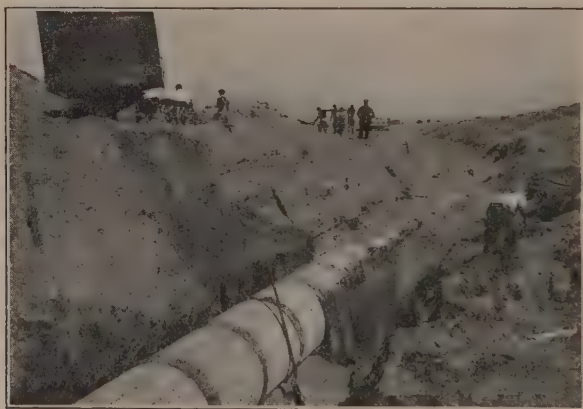


FIG. 4. — RIVER DIKE

Looking northerly along the inner slope of the river dike, showing method of placing concrete pipe drain and two grades of crushed stone surrounding it

a strip of riprap 20 feet wide having a thickness from 12 inches to $3\frac{1}{2}$ feet, and composed of stones of all sizes up to about 3 cubic feet in volume; (2) above the riprap and extending to elevation 25 a hand-laid paving; (3) from elevation 25 to elevation 31.4 a 12-inch layer of $1\frac{1}{2}$ -inch crushed stone.

For the riprap strip, trap rock as it came from the quarry (without being crushed) was used. The slope paving was composed of stones, roughly rectangular in shape, laid on edge and embedded in broken stone. Before the paving work was begun the slope on which it was to be laid was covered, first with a 6-inch layer of sand and then a 3-inch layer of crushed stone. The paving stone was laid in this crushed stone.

The depth of the paving stone was from 8 to 12 inches, and in general the width from 3 to 12 inches, with the length from 8 inches up to about 18 inches. The stone used in the early part of the paving in the late fall and winter of 1930-31 was native granite from Bolton and Glastonbury. Later, the most regular stones of the trap rock delivered for the riprap were used, and this resulted in a very good job.

To prevent water working through the dike above elevation 25 a blanket of silty sand was placed outside the river sand. For the portion along the river this blanket was 6 feet thick at elevation 25 and 2 feet thick at the top of the dike, elevation 35. For the dike from the river to the railroad this blanket had a uniform thickness of 1 foot.

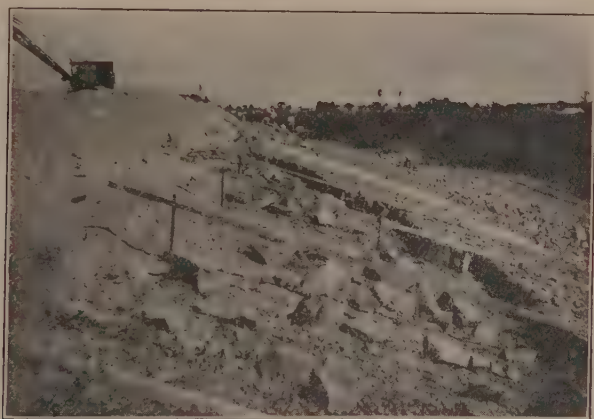


FIG. 5. — SLOPE PAVING

Looking northerly along the river slope of the dike,
showing the slope paving

On the outside of the dike all slopes not covered with stone have been seeded. On the inside the river sand was covered with 6 inches of the meadow material, and the slope for about one-half the length of the dike was seeded.

DRAINAGE OF DIKE

To drain away any possible seepage through the dike a reinforced concrete pipe drain, part 21 inches, part 24 inches, and part 30 inches in diameter, was laid along the inside toe for the length of a mile opposite the aviation field. An open ditch provides drainage for the remaining distance. This pipe and ditch also serve as a drain for the surface water from a portion of the meadow.

PRICES AND CONTRACTORS

For the sheet pile work the contract price was \$0.595 per square foot of cut-off wall in place. For the dike a few of the unit prices were as follows:

Silty sand embankment	\$0 38 per cubic yard
River sand embankment	23 per cubic yard
River sand fill in low areas	22 per cubic yard
Riprap	2 00 per cubic yard
Slope paving	1 60 per square yard

The clearing and grubbing contract was carried out by Pascal Ricci, New York City; the sheet pile cut-off, by L. E. McLaughlin, Inc., New London, Connecticut; the dike proper, by the R. C. Huffman Construction Company, Cleveland, Ohio. For the first-named contract nine bids were received; for the second, twenty-nine, and for the third, eight, the contract in each case being awarded to the low bidder. Under the dike there were two sub-contracts, — A. I. Savin of Hartford building the silty sand embankment, and the Arundel Corporation of Baltimore doing the dredging and completing the river sand embankment.

PURPOSE AND SCHEME OF OPERATION OF THE SOUTH MEADOWS PUMPING STATION, HARTFORD, CONNECTICUT

BY WILLIAM A. D. WURTS*

FUNCTIONS OF THE STATION AND ELEMENTS CONSIDERED IN THE DESIGN

THERE are two essential elements in the plan under which the South Meadows have been protected from periodic flooding. It was necessary first to prevent the waters of the Connecticut River from flowing back into the meadows during flood stages of the river. The dike has been constructed for this purpose. An area of approximately two square miles has thus been enclosed. The second necessary step in the flood protection plan is the removal of the water which would accumulate in the protected area behind the dike. The South Meadows Pumping Station has been constructed to perform this function.

* Assistant Engineer, Department of Engineering, city of Hartford, Connecticut.

Water from several different sources must be removed from the meadows. Rain falling in the protected area is, of course, the major factor in the problem. In designing the pumps, careful studies of the rainfall records were made, and the amount of water which may be expected to fall on the meadows was computed. A storm of intensity such that it may not be expected to occur at intervals less than once in ten years was adopted as the criterion. Not all the rainfall is included in the run-off of an area such as the one in question. Quite a bit of the rain is absorbed by the ground on which it falls. It was, therefore,

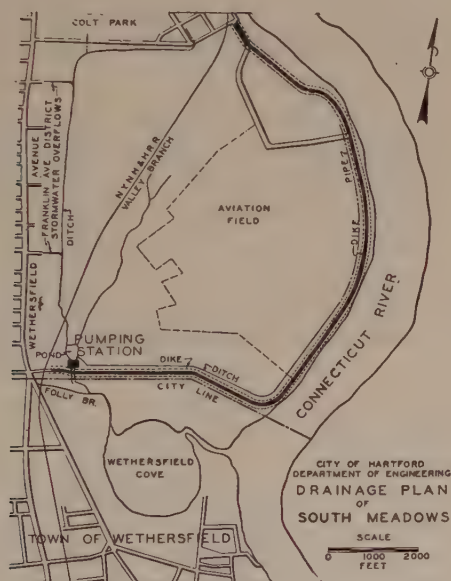


FIG. 6. — DRAINAGE PLAN OF SOUTH MEADOWS

necessary to modify the figures by a factor known as the percentage of run-off. This factor varies with the season of the year, with the nature of the ground surface, and with the duration of the storm, and quite extensive studies had to be made before reaching a final conclusion as to the expected quantity of water from this source.

Two storm water overflows from the Franklin Avenue sewer district discharge into the meadows, one near Old's Place and one near South Street. Each is six feet in diameter. Approximately 80 per cent of the storm water from approximately 800 acres of the southerly portion of

Hartford is thus conducted to the meadows. Although provisions have been made to enclose at some future time the flow so discharged in a tight conduit, leading directly to the river, it will be necessary to pump this water for some time; for the present development of the meadows hardly warrants the expenditure of large sums for the construction of works of this nature. Conduits have already been constructed under the dike, however, to prevent the disturbing of that structure when it is desired to complete this portion of the plan.

There are other minor factors which had to be considered in the determination of the amount of run-off. Ground water finds its way to the surface in portions of the meadows. A portion of Colt Park and the "Colts Meadow" district drain into the South Meadows. Some water may be expected to seep through the dike, since no earth dam can be said to be totally impervious. Although water from this source will not be in sufficient quantities to be apparent to observers, it was nevertheless included in the study of conditions. It was possible to compute the magnitude of the seepage, even before the dike was constructed, by making use of careful physical analyses of the soils used in the dike construction.

From the data obtained from studies of all the factors given above, it was possible to determine the inflow into the ponds adjacent to and north and east of the pumping station. Since water may be allowed to rise in these ponds within reasonable limits without inconvenience to anyone, the pumping capacity necessary could be reduced somewhat because of the storage effect.

It was finally decided that the equipment in the station should be capable of handling approximately 260 cubic feet of water a second, the equivalent of 120,000 gallons a minute, and it was then decided to install four 36-inch pumps, each of 30,000 gallons per minute capacity against a 20-foot head.

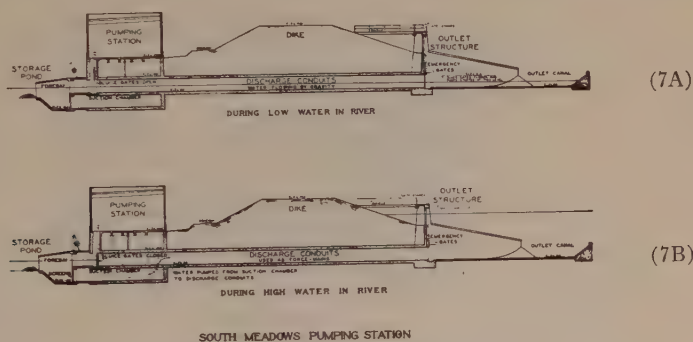
The construction of buildings and pavements in the meadows will increase the percentage of run-off mentioned above. The ponds in the vicinity of the pumping station may not always be available for storage, due to possible development of that portion of the meadows. Provisions were therefore made for the possible future installation of two more similar pumps.

The site on which the pumping station has been built was chosen because the topography of the meadows is such that the natural drainage is toward the southwest corner, and drainage ditches already constructed lead to that portion of the meadows. Upon completion of the design, contracts were let to Starkweather & Broadhurst of Boston,

Massachusetts (now the Starkweather Engineering Company, Inc.), for all the mechanical equipment, and to C. W. Blakeslee & Sons of New Haven, Connecticut, for the building and appurtenances.

GENERAL PLAN OF OPERATION

The general plan of operation may best be understood by reference to Fig. 7A and Fig. 7B. Fig. 7A shows the conditions that apply during normal stages of the river. The water in the pond behind the station flows by gravity directly through the station and through the discharge conduit "A" under the dike and into the outlet channel, being led to Wethersfield Cove through a ditch connecting with Folly Brook. The



FIGS. 7A AND 7B. — SOUTH MEADOWS PUMPING STATION, AND RELATION TO DIKE

main sluice gates in the station are left open as shown. No pumping is necessary under these conditions. The discharge conduit has three barrels, each 7 feet wide by 6 feet 6 inches high.

When the river rises above elevation 8.0, water would flow back through the discharge conduit and into the meadows, raising the water level in the ponds above a desirable maximum. It is then necessary to put the pumping station into operation. The main sluice gates in the station are closed, preventing further back flow into the meadows. The ponds are now full of water up to elevation 8.0. In order to take advantage of the pond storage feature mentioned previously, one or more of the pumps are started and the level of water behind the dike is reduced to elevation 5.0. Then as the water level in the ponds rises, due to rainfall or other causes, from one to four pumps may be operated, depending on the rate of accumulation.

Fig. 7B shows the conditions applying during the river stages above 8.0. Water from the ponds flows into the forebay through the screens (see also Fig. 9), into the suction chamber "B," from whence it is pumped to the discharge conduit "A" and out into the water outside the dike. The pumps are, of course, so constructed that they are capable of forcing water out through the discharge conduit against the pressure of the highest level to which the river may be expected to rise. From past records of the Connecticut River, covering a period of thirty years, it may be expected that pumping will be necessary for only 100 days in the average year, flow by gravity being possible during the remaining 265 days. The total amount of pumping to be done in the average year is estimated to be about 600,000,000 gallons.

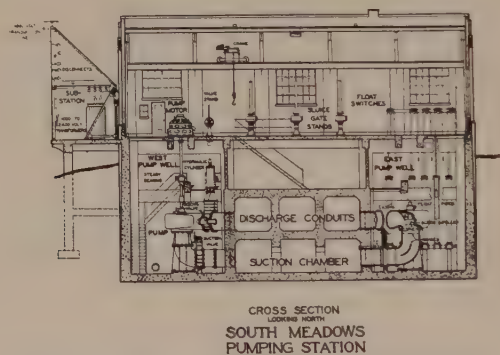


FIG. 8.—CROSS SECTION OF SOUTH MEADOWS PUMPING STATION

DETAILS OF OPERATION

Figs. 8 and 9 have been prepared to show the arrangement and interrelation of the several portions of the mechanical and electrical equipment.

Fig. 8 is a cross section through the east and west axis of the station, such as might be seen by an observer standing at the front of the station looking north, that is, toward the center of the city. Fig. 9 is a section through the north and south axis of the station, looking in an easterly direction.

It will be noted in Fig. 8 that there are two pump wells, one in the westerly third and one in the easterly third of the station. Each of these wells contains two pumps, with space for a possible third unit. Blanked off suction and discharge pipes as well as foundations and anchor bolts have been provided for these future pumps.

Between these wells at the very bottom of the station (see Fig. 8) is the suction well "B." Fig. 9 shows how the water from the pond and forebay enters the suction well through the screens. These screens prevent large pieces of wood or débris from entering the pumps. They may be lifted out of the water for cleaning by means of the hoists shown in the illustration. Above the suction chamber "B" are the discharge conduits "A," which run through the dike to the outlet structure. It may be noted in Fig. 8 that no water is pumped through the center of the three barrels in the conduit, it being merely for the necessary additional capacity under gravity flow conditions.

The top of the discharge conduits forms the floor of the heating boiler room and the vault for high-tension electric apparatus. (See Fig. 9.)

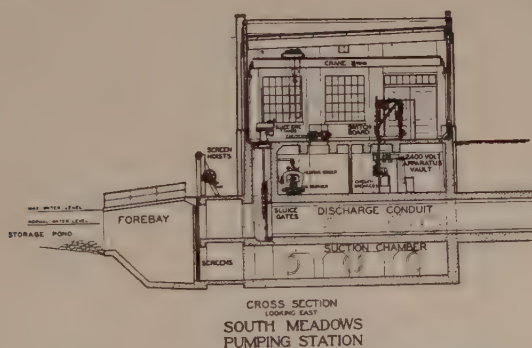


FIG. 9.—CROSS SECTION OF SOUTH MEADOWS PUMPING STATION, LOOKING EAST

Twenty-six feet above the bottom of the pump wells is the main floor or motor room. This is level with the ground in front of the station, and on it are mounted the main pump motors, the switchboard and various pieces of auxiliary equipment. The operator (except for periodic trips to the pump wells to check the bearing lubrication and the like) is stationed here, where all of the apparatus may be controlled, and where the performance of the pumps may be watched indirectly through the readings of the various meters and gauges.

The details of the several portions of the apparatus will be taken up separately.

PUMPS

The four 36-inch pumps are identical in construction, were built by the Morris Machine Works of Baldwinsville, New York, and are approximately twelve feet high. The water is drawn from the suction

well and discharged into the discharge conduit. The impeller may be seen in the cut-away view of the pump in the east well of Fig. 8. The impeller rotates at a speed of 450 revolutions per minute. The impeller is connected to the motor by a vertical shaft 5 inches in diameter. Concrete beams midway between pump and motor hold an intermediate or "steady" bearing, and, in addition, serve as support to the grating platform at elevation 10. These intermediate bearings, as well as the bearings on top of the pumps, contain integral oil circulators, insuring correct automatic lubrication at all times.

VALVES

Each pump has a 36-inch manually operated suction valve and a 36-inch hydraulically operated discharge valve. These valves are very similar to valves used in ordinary waterworks projects and were built in the Hartford plant of the Pratt & Cady Company (Reading Steel Casting Company). The suction valves are used only in connection with maintenance or repair work when it is necessary to drain a pump in order to enter it through the manholes provided for that purpose.

The discharge valve must be kept closed when the pump is not operating, to prevent the water from the discharge conduit from flowing back through the pump. Arrangements have been made so that when the pump starts, the valve opens automatically. When it is time to stop the pump, the valve is closed first. When it is fully closed, the pump automatically stops. The valves are constructed with two parallel discs, 36 inches in diameter, which slide up and down in the valve casing. Wedges are provided to seat the discs tightly when the valve is fully closed. The discs are lifted and lowered by city water pressure acting on a piston within the cylinder at the elevation 10 level. A four-way cock admits water under about 95 pounds pressure to either the upper or under side of the piston, as the valve is closed or opened, respectively. Water from the opposite side of the piston is exhausted to the sump. Each four-way cock is operated by a thruster, which may be seen mounted on the side of the hydraulic cylinder. These thrusters, built by the General Electric Company, contain a motor driven centrifugal oil pump, a small reservoir and a piston and cylinder. The thruster motor is energized automatically when the discharge valve is to be opened, and, when energized, rotates the oil pump forcing the piston through the thruster cylinder and moving the four-way cock to the proper position to open the discharge valve. When the discharge valve is to be closed the thruster motor is de-energized, and weights attached to the four-way cock return it to the closing position. Manual operation

of the hydraulic valves is possible by means of geared hand wheels with screw stems mounted on the main floor. These need be used only in case of failure in the water pressure.

MOTORS AND EXCITERS

The pumps are driven by 225 horsepower General Electric vertical motors mounted on the main floor above the pumps. These motors operate on 2,400 volt, three-phase, alternating current and are of the type known as synchronous machines.

Since direct current for excitation is not otherwise available, two General Electric motor-generator sets, known as exciters, mounted on the main floor just east of the stair well, are provided for this purpose. Each generator furnishes direct current at 125 volts and is driven by a 20 horsepower alternating current motor. Each is capable of supplying direct current for the field of all the large motors. Two units are provided merely as a safety precaution in case of the failure of one to function properly.

Mounted on top of each pump motor, inside the top frame, is a thrust bearing. This bearing runs in a bath of oil and carries the load of the moving parts of the motor, the weight of the shaft and impeller, and the water thrust.

SLUICE GATES

The three main sluice gates across the discharge conduit in the station (see Fig. 9) are left open when gravity flow is possible, but must be closed when pumping is necessary, to prevent back flow from the river into the meadows. Each gate weighs 10,000 pounds and is lifted and lowered by means of a motor-driven mechanism mounted on the main floor. (See Sluice Gate Stands, Figs. 8 and 9.) Hand wheels are provided for manual operation when necessary. Automatically operated limit switches stop the gates at the fully opened or fully closed positions.

A second set of five sluice gates mounted on the outlet structure south of the dike is for use in emergencies or during maintenance work requiring the conduits to be de-watered. The three easterly gates of the five protect the station discharge conduits. The westerly two prevent water from entering the double-barrelled culvert constructed as part of the future conduit for storm water from the Franklin Avenue sewer district.

The gates and stands, both in the station and on the outlet structure, were built by the Chapman Valve Manufacturing Company.

AUTOMATIC CONTROL

Full automatic control of the apparatus in the station is provided, so that the operators need not be particularly skilled and have only to maintain the proper oil level in the bearings, and watch in a general way the operation of the machines. Manual control for all units is, of course, provided, so that more operating flexibility may be obtained when a skilled operator can be present.

The automatic control is arranged to close the main sluice gates in the station as the river rises above any predetermined elevation and to open them again when the river falls to the proper level. Similarly, when the sluice gates are closed, one pump will be automatically started if the level of the water in the ponds rises above a predetermined elevation. If the water continues to rise faster than one pump will handle, a second pump will be started, and so on until all four pumps are running. When the pond has been pumped down to the proper level, the pumps are shut off.

All this is accomplished by a set of seven float switches. Two of these are actuated by changes in level of the river and five by changes in the forebay level.

The method of operation of these switches may be seen by referring to Fig. 8. Water from the suction chamber is admitted to the float pipe, and fills that pipe to the level of water in the forebay. Changes in forebay level, therefore, immediately produce similar changes in the level of the water in the float pipes, causing the copper float to rise and fall. To the floats are attached copper cables extending up through the main floor, through the arms of the float switches, over pulleys, and back down again to counter-weights of proper mass to balance the floats. Movable buttons are attached to the copper cables. These buttons throw the float switches on or off at any predetermined float elevation.

ELECTRICAL FEATURES

Electric power at 11,000 volts is conducted from a transmission line of the Hartford Electric Light Company near the Valley Railroad to the station along a pole line on the dike right-of-way. Outside of, but attached to, the west wall of the pumping station is the transformer substation. Here are three large transformers which reduce the voltage from 11,000 to about 2,400 volts. Mounted on the steel framework constructed on the substation platform are the lightning arresters,

primary fuses and disconnecting switches, as well as a small 2,400 volt to 220/110 volt lighting transformer for the station illuminating current.

Power at 2,400 volts enters the station and is conducted by cables encased in a concealed steel conduit to the vault on the elevation 10 floor, underneath the switchboard. This vault is, of course, fireproof. Keys to the vault door are in the possession of authorized persons only. All the 2,400 volt apparatus is confined within this space. The main disconnecting switches, as well as disconnects for each unit, are mounted on a pipe framework which also supports the 2,400 volt bus, the large oil circuit breakers and oil-immersed motor contactors. These contactors make and break the 2,400 volt current to the four pump motors and are operated by large magnets energized through relays on the switchboard on the floor above. Current and potential transformers for operation of meters and relays are also found here, as well as four 15 KVA, 2,400 volt to 240 volt transformers for the operation of auxiliaries, such as the sluice gate motors, exciters and the like. One of these transformers furnishes current for the automatic and manual control systems.

Above this vault is the switchboard proper. This is divided in two parts. On the seven operating panels (see Fig. 9) are all the switches, meters and indicators necessary in the operation of the station. This is a dead-front board; that is, no live parts are accessible to the operator, and it is therefore impossible for him to receive a shock or be burned. A second set of seven control panels behind the operating panel (see Fig. 9) contain all the relays, time switches and the like incorporated in the manual and automatic control systems. These latter panels are enclosed for protection by a steel and wire partition and are hinged so that they may be opened like doors, for convenience in maintenance work.

The highest voltage found on the switchboard is 240; for all the 2,400 volt wiring and apparatus has been confined, in the interests of safety, to the vault below.

Wires from the switchboard lead to a pull-box on the floor between the panels. From this pull-box steel conduits embedded in the concrete lead to all the various pieces of electrical apparatus about the station. Approximately 750 feet of electrical conduit are concealed within the main floor. The switchboard and control apparatus were built by the Sundh Electric Company of Newark and were installed by the Griffing-Schofield Electric Company of Hartford.

FUNCTIONS OF ELECTRICAL APPARATUS

The panel at the extreme right of the operating face of the switch-board controls the incoming line and supports the station clock as well as two recording meters and one indicating gauge. A handle for manual operation of the main circuit breaker is provided, and is connected by a pipe mechanism to the breaker in the vault underneath. Coils incorporated in the handle, together with time delay relays, are arranged to trip the breaker and shut off the power in case of short circuit or serious overload. Colored indicator lights show whether the breaker is open or closed.

The next panel to the left is for the control of the sluice gates. A switch at the top with an indicating light transfers the sluice gates from automatic to manual control. A manual switch for each gate provides means of opening or closing the gates at the will of the operator. Red and green indicating lamps are provided for each gate, the red light showing that the gate is fully closed, the green indicating that the gate is fully open. Mounted on this panel there is, in addition, a transfer switch so arranged that any one of the pumps may be connected to any one of the float switches. Under automatic control, No. 1 float switch always is actuated first. It would be undesirable always to have the same motor and pump start first, since the wear on their bearings would be greater than on the others. Periodic movement of this transfer switch will equalize the wear to a considerable extent. Under the transfer switch is mounted a circuit breaker handle, with trip coils and indicator lamps for the control of the breaker which protects the 240 volt transformers. On the secondary hinged panel behind this panel are the sluice gate motor contactors as well as time relays which perform several functions in connection with the automatic control system.

The operating panel next to the left is the exciter panel and is for the control of the motor-generator sets, or exciters. A transfer switch is provided for shifting periodically from one exciter to the other to equalize wear. Manual switches for hand control of both exciters are included, together with red indicating lamps to show which exciter is operating. A volt meter and an ammeter for each unit are mounted on this panel, with an adjustable rheostat for control of the generator voltage. A manual switch for the automatic sump pump is included with the other apparatus on this panel. On the control panel behind the exciter panel are found a knife switch, fuses and an automatic contactor for the sump pump, together with full control apparatus for the

exciters. This apparatus includes knife switches, fuses and contactors for the exciter motors, and, at the very bottom, automatic direct current contactors for the generators. These latter contactors are electrically and mechanically interlocked to prevent the operation of both generators at once.

The next four operating panels are identical, and each is for the control of one of the pumping units. At the bottom of each panel is the circuit breaker handle with trip coils for control of the circuit breaker mounted below. A green indicating lamp shows that the breaker is closed. Above the breaker handle are two switches: one three-position switch places the pump unit under automatic control, allows it to be started by hand, or shut off, at the will of the operator. A second switch allows the discharge valve of the pump to be operated for maintenance work without starting the pump. Red and green telltale lights indicate whether the discharge valve is closed or open, respectively. At the top of the panel are meters indicating the amount of both alternating and direct current being used by the motor. A red lamp to the right of the circuit breaker handle indicates that the pump motor is running. On the control panels at the rear are found the various time relays necessary for the control of the motors, including the time relay and contactor, for automatically applying the direct current to the field of the motor at the proper time.

Various protective devices and safety features have been incorporated in the design. Each circuit has, as previously stated, a breaker for the interruption of overload current. Each motor in the station, whether large or small, has temperature overload protection; that is, if by reason of overload, or otherwise, the windings of the motor become unduly heated, the motor is stopped. Since the pump motors draw a very heavy current during their starting period, relays have been arranged so that only one of the pumps can be started at a time, either under automatic or manual control. The second pump is retarded in starting until the previous one is running under normal current conditions. This is necessary to prevent an excess inrush of current from the transmission line in quantity sufficient to affect the lights of other users of current from the same line.

GAUGES

A dial indicating gauge on the incoming line panel of the switchboard indicates the level of water outside the dike. The red hand of this gauge shows the level at which the sluice gates are to be closed and the pumps started.

A large indicator board adjacent to the switchboard shows at a glance the elevation of the water in the forebay and the ponds north of the station.

An automatic recording gauge equipped with two pens has been installed on the first panel of the switchboard and makes a continuous graphical record of the water level, both outside the dike and in the forebay or ponds. Mounted at the right of this gauge is a recording wattmeter which graphically shows when each pump was stopped and started and indicates the amount of power used at any time. The charts in these gauges give a continuous record over a period of two weeks and are driven by electric clock work. By removing and comparing these charts it is possible to obtain an absolute check on the operation of the station. It can readily be seen whether under manual operation the attendant has at any time failed to perform his duties properly; and if, under automatic operation, any of the control apparatus should fail to function, the record will be of great value in determining the difficulty.

AUXILIARY APPARATUS

A seven and one-half ton traveling crane has been installed as a necessary adjunct to maintenance work. By its use any of the apparatus may be lifted or moved about. Sufficient openings through the main floor are provided, so that even the pumps and other equipment in the wells may be handled by the crane.

A steam heating system with automatic oil burner has been installed. Adjustable thermostats control the heating system, so that when the operator or maintenance men are present the building may be comfortably warm. When no one is to be in the building the thermostats are adjusted to a lower temperature, merely enough heat being provided to prevent freezing of the water in the pumps and other apparatus and to eliminate the possibility of any undue dampness in the building which might be detrimental to the electrical equipment.

A small automatic pump has been installed in the sump in the west well. A similar sump in the east well is connected by piping to the west well. Any water which accumulates in either of the wells is thus pumped out of the station. The motor for the pump is mounted on the main floor and is controlled by a float switch actuated by the level of water in the sump. The waste water exhausted from the hydraulic cylinders of the 36-inch pump discharge valves is also removed from the station by the sump pump.

PUMP TESTS

One of the most interesting phases of the design of the pumps was the use of shop tests of 20-inch model to predict impeller performance. The results of the model tests were computed and used to construct expected performance or guarantee curves for the 36-inch pumps, it having been deemed inexpedient to attempt to make shop tests of pumps having capacities as great as 30,000 gallons a minute.

When the field tests were made, after completion of the station, the predictions of performance based on the model tests were substantiated with gratifying accuracy. The discharge and efficiency at a 25-foot total dynamic head as predicted from the model tests were to be 30,600 gallons a minute and 89 per cent, respectively. The field tests indicated that 31,400 gallons a minute were delivered at this head and that the efficiency was slightly in excess of 90 per cent.

SOIL STUDIES ON HARTFORD DIKE

BY GLENNON GILBOY*

THE suitability of the silty sand as a dike material was largely dependent upon its resistance to the seepage of water. In order to form a preliminary opinion on this question, borrow pits were excavated, and the loose soil was replaced in the pits and tamped in horizontal layers to imitate construction conditions. Undisturbed samples were then removed and tested for permeability.

The results of tests on the finest and coarsest samples are reproduced graphically in Fig. 10. The double circles represent the results of tests on the undisturbed samples. The small circles and the lines show the results of tests on the same materials broken up and tested in different states of compactness. The correlation between the two sets of tests is interesting as an indication of the fact that with this particular material substantially correct results can be obtained without removing undisturbed samples from the fill. This is an important item with respect to control tests on the material during construction, as it permits the use of the simplest type of apparatus.

* Associate Professor of Soil Mechanics, Massachusetts Institute of Technology, Cambridge, Mass.

PERMEABILITY

The range of permeability was from about 0.5×10^{-4} to 30×10^{-4} centimeters per second; that is, the coarsest material was about sixty times as pervious as the finest. Therefore, the only conclusion that could be drawn from these figures was that the total seepage through the dike with flood water at the top of the impervious section would be somewhere between 0.14 and 8 cubic feet per second. The more carefully the finest constituents were selected, the more closely would the lower value be approached.

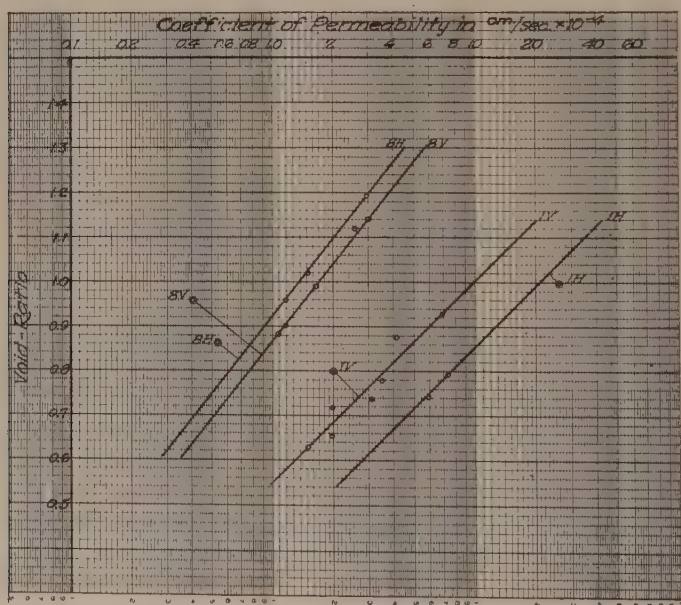


FIG. 10. — TESTS OF SAND

The soil composing the impervious section of the model was taken from several different locations, and was thoroughly mixed before placing. It was therefore to be expected that its permeability would be somewhere between the two extremes previously determined. The value found was about 7×10^{-4} centimeters per second. Introducing this figure into theoretical calculations results in a seepage for the whole dike, with flood water at the top of the impervious section, of 1.94

cubic feet per second. The value obtained from the model test was 1.85 cubic feet per second. The close agreement indicates that the theory and the permeability measurements are quite reliable.

FLOW LINES THROUGH MODEL

On rare occasions floods may occur which will lift the river level above the top of the impervious section. In order to study this condition a test was made with the water level at extreme flood height.

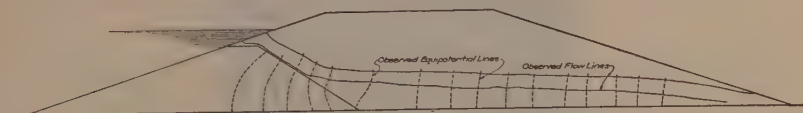


FIG. 11. — CHARACTER OF FLOW IN MODEL

Fig. 11 shows the character of flow in the model, as given by observations on dye lines and piezometers. The total seepage was found to be 19.2 cubic feet per second, more than ten times the amount through the impervious section in the preceding case.

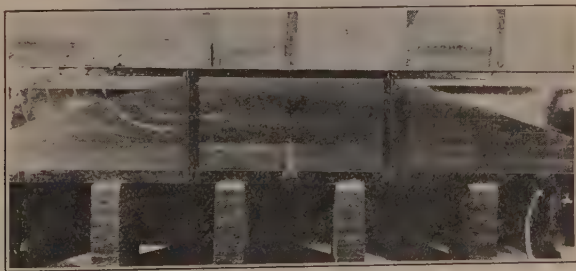


FIG. 12. — FLOW LINES THROUGH MODEL AS CONSTRUCTED WHOLLY OF SAND

The test on the model constructed entirely of sand merely showed that this type of dike was impractical on account of excessive seepage. Values as high as 61 cubic feet per second were obtained. On account of the substantial velocity of flow through this model good flow lines were obtained, as shown in Fig. 12.

STUDY OF STABILITY OF MODEL

The model tests were particularly useful in affording an idea of the stability of the dike under various conditions. The first stability test was made inadvertently, when a pane of glass broke and it became necessary to draw off the water. This condition corresponds to a rapidly



FIG. 13. — EFFECT OF RAPIDLY RE-
CEDING WATER IN MODEL

receding flood in nature. It was found that the exposed surface of the impervious section sloughed noticeably as it drained. Fig. 13 gives an indication of the amount of damage.

WAVE ACTION ON MODEL OF DIKE

After the tests on the first model were completed an attempt was made to determine the effect of wave action on the river slope. Waves 4 to 6 inches high, artificially created, ate their way into the slope at a fairly rapid rate. The result of twenty minutes of wave action is indicated in Fig. 14. It can be observed that the waves undermined the slope, and that the material assumed an inclination considerably flatter than the original 3:1 angle.

Both these tests indicated the necessity for thorough protection of the river slope against erosion. As Mr. Fay has pointed out, the problem was adequately solved by the use of riprap and stone paving.

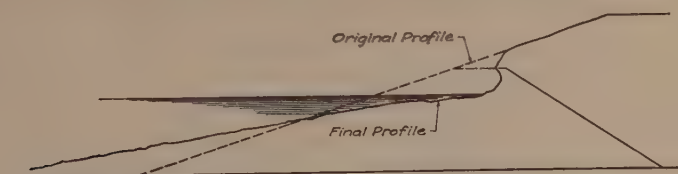


FIG. 14. — EFFECT OF WAVE ACTION ON RIVER SLOPE

The stability of the coarse portion of the dike was also studied. Fig. 15 represents an extreme condition. Before the model was destroyed the water was allowed to rise until it overtopped the dike, producing considerable damage. There is no reason to fear such an occurrence in nature; but a similar effect of smaller degree was observed on that portion of the landward slope below the line of saturation. It was found



FIG. 15. — EFFECT OF
OVERTOPPING OF
MODEL OF DIKE

that the sand would not stand on a slope steeper than 1 : 4 under flowing water, even at a low velocity. The recommendation was accordingly made that care should be taken to provide a substantial rock toe or similar drainage element at the landward end, to ensure that the line of saturation would at all times remain well within the landward slope.

MODEL STUDIES OF DIKE FOR PROTECTION OF HARTFORD SOUTH MEADOWS

BY KENNETH C. REYNOLDS*

THE VALUE OF MODEL TESTS

UNTIL recently the design of most hydraulic structures has been based on practical experience only. If failures developed, either the damage was repaired or the structure was redesigned. In either case the undertaking represented a considerable expenditure of time and money without a feeling of security that the structure would successfully perform its task.

The old methods of design are now being supplemented by a study of a small replica or model of the structure to which water is introduced to simulate the actual conditions in nature. Alterations may be easily and inexpensively made until the desired results are attained.

Laboratories for making such model studies were first developed in Germany, and her scientists have made great strides in developing the art. The speaker was honored by this Society by being selected as the first recipient of the John R. Freeman Traveling Scholarship for 1927 to 1929. He made a thorough study of European river hydraulic laboratories, and, on his return to the Institute, established such a laboratory there.

NATURE OF PROBLEM

Several questions relating to the Hartford South Meadows dike required further studies, and, in order to settle them, it was decided to construct a model of the dike in the River Hydraulic Laboratory at the Institute. The research work was placed in charge of Professor Glennon Gilboy and the speaker. The studies themselves were accepted as the basis of a thesis for the degree of master of science by two graduate civil engineering students, Messrs. S. J. Buchanan and J. H. Kenyon.

After considerable preliminary study, it was decided to simulate the natural dike by means of an undistorted model on a scale of 1 to 15, constructed from the materials intended to be used in the actual project. It was believed that this scale factor would produce a model large enough so that accurate measurements could be expected and at the same time not so large as to be too unwieldy to handle in the laboratory.

* Assistant Professor of Hydraulics, Massachusetts Institute of Technology.

By utilizing the same materials in the model as in the dike, the permeability coefficient would be unchanged, thereby eliminating one uncertain factor in the interpretation of the results.

The plan of study included measurements of the actual seepage through the model dike at various flood stages; measurements of the variation in energy of the seepage water throughout the dike section; observations on the character of the flow through the dike; studies of the effect of the seepage water on the physical properties of the material, with especial regard to the stability of the slopes; and observations on the probable resistance of the materials to erosion by moving water.

DESIGN OF EQUIPMENT

General

In designing the model flume or tank in which the tests were to be conducted, certain fundamental conditions had to be fulfilled, among which may be mentioned: the model had to be entirely contained in a comparatively rigid frame, water-tight, with at least one transparent face and with sufficient end clearances to allow the establishment of satisfactory headwater and tail-water conditions. Provision had to be made for accurate automatic control of the headwater level and for collecting and discharging the seepage water. Some means for the introduction of color into the headwater were thought necessary in order that the flow lines might be visually traced. Finally, the tank had to be so located that the models could be conveniently constructed, the water supply continuously available, and the entire apparatus readily accessible for observations and photographic records.

Model Tank

The dike tank, designed and constructed especially for these tests, was approximately 20 feet long, 2 feet 6 inches deep and 2 feet wide. Fig. 16 is a front view of the tank with the first model in place. The glass face was 15 feet long and was made up of three $\frac{3}{4}$ -inch plates, set into the frame in putty and made true and plane. The headwater is on the left and the tail-water on the right.

Water Supply

The headwater was supplied through a pipe and hose connection to the Cambridge City water supply, regulated by a throttle valve. After a preliminary run, it was found that the city water was charged with air which clogged the voids of the model dike and gave erroneous results. This was corrected by introducing steam under low pressure into the water supply pipe just before it entered the tank. The temperature of the water was raised so that, as the water passed through the dike, there was always a drop in temperature, thus clearing the voids of entrapped air.



FIG. 16. — DIKE TANK WITH MODEL NO. 1 IN PLACE

In order to provide a constant headwater level over an indefinite period of time without attention, an overflow device was necessary. Fig. 17 shows this device as finally perfected. A funnel, which could be set by a micrometer screw adjustment for any desired water level, passed the waste water into a hose connection which was connected by a water-tight joint to the waste outside the tank.

Outlet

In the tail-water end of the tank an outlet connection was introduced, controlled by two gate valves. One valve led to a drain line, the other opened vertically downward. In normal operation the drain

line was open. When measurements of the quantity of seepage were being taken, this valve was closed and the other valve opened, and the water allowed to escape until uniform flow existed, when the water was collected in a graduate, the time being taken with a one-fifth second stop watch. A screen with a gravel and sand filter above was placed inside the tank over the outlet to allow the water to escape without carrying off the finer constituents of the soil.

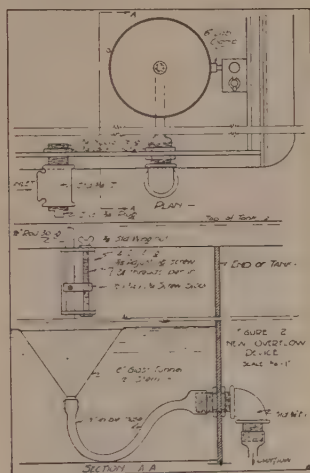


FIG. 17.—OVERFLOW DEVICE

Piezometers

In the steel plate forming the back wall of the tank were introduced 40 piezometer openings (Fig. 18). They were located so as to give sufficient readings of pressure in the proposed models. A $\frac{1}{8}$ -inch brass nipple was screwed into the plate from the outside and held a 100-mesh screen against a shoulder, thus preventing sand from clogging the gage. At first the piezometers were connected by rubber tubing to a common gage board. Entrapped air in the tubing caused errors in the readings, and these were eliminated by carrying the connections at any one vertical to a gage board, the rubber connections being always horizontal. The glass piezometer tubes were $\frac{1}{8}$ inch inside diameter.

Dye

In order to trace out the flow lines followed by the percolating water, an arrangement was made whereby a dye could be introduced through a small tube into the headwater slope of the model. Various dyes were tried, but that finally adopted was fluorescin, a greenish colored dye. Drawn glass nozzles (Fig. 16) were supported on rods which, in turn, were carried by clamps fastened to the upper edge of the tank and designed to be adjustable in all directions. The tip of a nozzle was placed so as to be practically against the glass front of the tank and just beneath the surface of the soil, to prevent the diffusion of the dye in the headwater.



FIG. 18.—PIEZOMETERS
AT BACK WALL OF
TANK

The proper control of the dye was quite a problem, and the scheme finally adopted is shown in Fig. 19. The upper reservoir or auxiliary supply reservoir was filled through the rubber tube shown toward the front at the mouth of the flask. The dye passed through it and the stopper into the auxiliary supply reservoir. From this reservoir the dye passed to the dye supply reservoir, the small globular vessel. The dye in this reservoir was at atmospheric pressure, the level being maintained within narrow limits by means of the auxiliary flask above, which fed the supply reservoir at intervals as the level in the latter dropped and allowed air to enter the auxiliary flask through the vertical

tube on the outside of the globular vessel, thus unbalancing the pressure above the dye in the upper flask and permitting sufficient dye to pass through the bent supply tube so as to restore the level of the dye. In this way, an excess head of about 6 inches was maintained practically constant on the supply system.



FIG. 19.—APPARATUS FOR
CONTROLLING INTRO-
DUCTION OF DYE

Leading off the main supply line were the individual dye lines which bring the dye to the nozzles. Each line was carefully controlled by a Lunkenheimer valve, a very fine adjustment being necessary.

Materials

Samples of the proposed borrow pit materials were sent to the Institute from the site, representative samples both of the alluvial silt and of the pervious river sand being selected for the models.

MODEL No. 1

General Layout

The first study was made on a proposed section, the dimensions and materials of which are indicated in Fig. 20. It was the intention to construct the impervious section from material borrowed from the alluvial flood plain, placed as a roll fill. After the completion of this portion of the dike, the pervious material was to be dredged into place from the bed of the river.

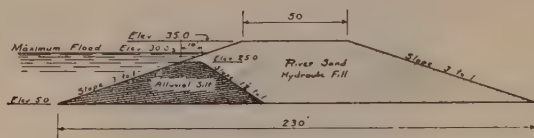


FIG. 20. — TYPICAL CROSS SECTION OF PROPOSED DIKE, MODEL No. 1 (SCALE OF MODEL 1:15)

The impervious portion of the section was intended to reduce to a relatively small value the seepage through the dike. Its top elevation of 25 was chosen, because none but the most extreme floods rise above this level. The heavy pervious section was intended simply to furnish stability and also to provide a 50-foot crest upon which a highway could later be constructed.

Construction of Model

The impervious section of the model was constructed from the fine alluvial silt from the south end borrow pits. The material was thoroughly mixed dry in its original condition and deposited in the model tank by hand in horizontal layers carefully tamped in place. The section was allowed to overrun the final lines and was later trimmed to the section shown.

The material for the pervious section of the model was a mixture of the river sand from two samples. In order to simulate to an extent the conditions obtained by hydraulic fill, the material was thoroughly mixed, saturated and deposited loosely under water in single shovelfuls, then mixed and levelled by hand. During this operation the water level was kept an inch or so above the top of the finished portion of the pervious section, and operations were so carried on that the saturation of the impervious section proceeded from the bottom toward the top in

order that as much air as possible would be driven out of the voids. The pervious section was brought up above the finished lines, and, after having been allowed to drain, was trimmed off to the final shape.

Scope of Tests

From preliminary observations it was evident that, in order to establish constant conditions under any given headwater stage, a considerable length of time would be required for any one test. On account of this time element it was decided to investigate both models for two limiting conditions: one in which the headwater stage was at the top of the pervious section (elevation 25), and one in which the level was at the maximum recorded flood level (elevation 30).

Method of Testing

During a test run, several observations were taken. The levels of the various piezometers were read at regular intervals, the data being taken in millimeters. Observations were simultaneously taken of the quantity of seepage, the data being recorded in cubic centimeters per minute. The tests were continued until successive piezometer observations gave the same values. With the water at elevation 25 nine days were required for this model to reach equilibrium conditions, and with it at elevation 30 twenty-one days.

MODEL No. 2

General Layout

The second study was intended to furnish information on the utility of a dike constructed entirely of the coarse material dredged from the river bed, and also to study the effect, if any, of the presence of a layer of alluvial silt underlaid by coarse material beneath the dike. Borings indicated that the South Meadows area, blanketed with alluvial silt, is underlaid by a stratum of coarse sand and gravel, below which is clay extending to an indefinite depth. The clay being to all intents and purposes impervious, it was decided that in the second model the bottom of the tank should represent the top of the natural clay layer; the coarse sand and gravel stratum should be represented by a layer of Plum Island sand; and the alluvial silt blanket should be simulated by a layer of the actual material. In the contemplated dike, seepage from

the river through the sand and gravel layer was to be cut off by sheet piles extending from the natural ground surface into the clay layer. A cut-off to represent these sheet piles was included in the second model. The dimensions and material of the second model are shown in Fig. 21.

Construction of the Model

The first step in the construction of the model was to place the model sheet pile cut-off just upstream from the center row of piezometers. The cut-off was formed by a piece of 22 gage sheet iron, 8 inches high, extending across the full width of the tank and connected to the bottom and back with putty and to the glass with Canadian balsam. Water was allowed to run into the headwater end to demonstrate the water-tightness of the cut-off.

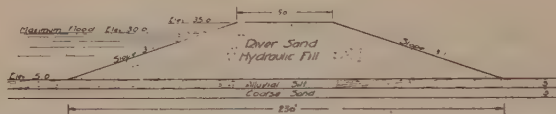


FIG. 21. — TYPICAL CROSS SECTION OF PROPOSED DIKE, MODEL NO. 2 (SCALE OF MODEL 1:15)

To imitate the sand and gravel layer, a 4-inch layer of Plum Island sand was spread over the entire bottom of the tank by hand and carefully levelled with a screed.

Above the sand was placed a 4-inch layer of the alluvial silt, extending beyond the proposed dike section but not covering the entire length of the tank, thereby leaving free access for the water into and out of the sand layer. The material was tamped into place by hand and levelled with a screed.

The model of the dike was built to simulate, so far as possible, the actual conditions resulting from sluicing operations on the river sand. The scheme finally adopted used a hog box, or mixing chamber, fitted with a sluicing pipe made of a length of $1\frac{1}{2}$ -inch fire hose. (Fig. 22.)

During the sluicing operations a core pool was maintained at all times. It became apparent that an actual segregation of the material into a core was not taking place on account of the lack of sufficient fines in the river sand. It is believed that this method gave results very closely approximating what would result in the actual structure.

The sluicing operation was carried out so that the slopes were always above the final lines, after which the section was trimmed to that shape previously shown.

Scope of Tests

The tests were made with the water at the same levels as used for the first model, one at elevation 25 and the second at elevation 30.



FIG. 22. — MODEL NO. 2 UNDER CONSTRUCTION, SHOWING SCHEME USED TO SIMULATE HYDRAULIC FILL

Method of Testing

Observations during the test runs included readings of the piezometers, measurements of the quantity of seepage, observations on the character of flow as indicated by dye lines, and observations on various items of behavior of the model, such as sloughing at the toe and bulking in the headwater section.

With the water at elevation 25 nineteen days were required for conditions to reach an equilibrium, and with it at elevation 30 thirteen days were necessary.

Discussion

HARRISON P. EDDY:* An inspection of the completed dike and pumping station, such as the writer had opportunity to make recently, gives the impression of a needful engineering work, well done, but it falls far short of giving an adequate impression of the problems involved and the studies made in connection with design, and the thoughtful planning and use of available labor-saving machinery in construction. A symposium like that presented by the several authors is necessary and distinctly helpful in forming an accurate mental picture of the magnitude of the undertaking.

The papers illustrate in an unusual way the remarkable development of the art of engineering, and the sciences upon which it is based, during the past sixty or more years.

One cannot but be impressed by the difference in the bases of design of the early dike and the one under consideration. The first was built according to judgment based upon experience of men who doubtless were used to dealing with physical conditions in the field, by means of the tools then available. Such tools were picks and shovels, and ox and horse drawn wagons and carts. When they are contrasted with the shovels, dredges, draglines, bulldozers and other mechanical equipment used for handling large quantities of earth, one recognizes that the present is an entirely different era from that when the first dike was built.

The new dike was designed with the aid, not only of practical experience, but of the most recent scientific developments and discoveries of the engineering sciences, such as soil mechanics. Even the application of these sciences was not by means of rules and formulas alone, but Mr. Clarke and Messrs. Fay, Spofford and Thorndike took advantage of the opportunity of making actual tests to check theory, and afford as sound a basis of design as was possible.

* Metcalf & Eddy, Consulting Engineers, Statler Building, Boston, Mass.

OF GENERAL INTEREST

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETINGS

Boston Society of Civil Engineers

OCTOBER 18, 1933. — A regular meeting of the Boston Society of Civil Engineers was held this evening at the Engineers Club and was called to order by the President, Arthur W. Dean. One hundred and twenty-five members and guests were present. Previous to the meeting 88 persons attended the buffet supper.

The President announced the death of J. Waldo Smith, who died on October 14, 1933, and who had been a member since January 27, 1904.

Upon recommendation of the Board of Government it was —

Voted, "That the Board of Government be authorized to use, in so far as necessary, the current income from the Permanent Fund for current expenses of the Society."

This matter will be finally acted upon at the next meeting of the Society.

The President announced that the next meeting will be the Annual Joint Meeting designated as Student Night, to be held in Chipman Hall, Tremont Temple.

The President called attention to the new bulletin of the Engineering Societies of Boston, which is expected to be issued weekly.

The President introduced Mr. Asa H. Morrill, Assistant Chief Engineer, Boston & Maine Railroad and Maine Central Railroad, who gave a talk on the "New Tidewater Facilities of the Portland Terminal Company at Portland, Maine."

This included a description of the new wharves and equipment, together with a discussion of the methods of operation. One of these wharves is equipped with diggers for handling coal, China clay,

etc.; another, with transit shed and machinery for handling baled pulp, lumber and general cargo; the third, with gantry cranes for handling ships' cargo from ship to shore, and Burton masts and equipment for handling China clay.

Discussion of the paper was presented by John Ayer, of the firm of Fay, Spofford & Thorndike, Consulting Engineers on this project; Charles H. Priest, manager of Marine Terminals, Portland Terminal Company; Frank C. Shepherd, Consulting Engineer; Edgar S. Dorr and Charles E. Nichols, Consulting Engineers.

The paper was illustrated by lantern slides.

The meeting adjourned at 8.30 P.M.

EVERETT N. HUTCHINS, *Secretary*.

Designers Section

OCTOBER 11, 1933. — A meeting of the Designers Section of the Boston Society of Civil Engineers was held Wednesday evening, October 11, 1933, at the Society rooms. The minutes of the May meeting were read and approved. The chairman then introduced Mr. J. Stuart Crandall, of the Crandall Engineering Company, who spoke on "Under-water Operations." He spoke particularly about diving and the difficulties of doing under-water construction work. He also explained several methods of facilitating the work of the diver by the use of templates, etc. A diving suit was shown and the various parts described. Many illustrations of typical under-water construction jobs were shown and explained. Several examples of deterioration of under-water masonry work brought out the need of periodical inspection of these structures.

There were 38 members and guests present.

HENRY BRASK, *Clerk*.

Designers Section

NOVEMBER 8, 1933. — A meeting of the Designers Section of the Boston Society of Civil Engineers was held on Wednesday evening, November 8, 1933, at 6.15 in the Society rooms, Tremont Temple.

Dr. Arthur Casagrande of Harvard University gave a paper on "Some Observations of Current Developments in Foundation Engineering, Soil Mechanics and Hydraulics in Europe." Dr. Casagrande devoted most of his time to some of the recent research and design work of Dr. Terzaghi, describing particularly the Bou Hanifia Dam in Algiers, North Africa, and the methods used to prevent erosion of the soil under the dam. A new precision leveling method devised by Dr. Terzaghi was described by the speaker in connection with a discussion of settlement of structures built on clay in various European cities. A short discussion followed on the properties and behavior of clays.

There were forty members and guests present.

HENRY BRASK, *Clerk*.

APPLICATIONS FOR MEMBERSHIP

[November 20, 1933]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of fifteen (15) days from the date given.

For Admission

WILBUR, JOHN B., Belmont, Mass. (Age 29, b. Oakland, Me.) Graduate of Massachusetts Institute of Technology with degrees of S.B. in Civil Engineering, 1926; S.M. in Civil Engineering, 1928; Sc.D. in Civil Engineering, 1933. Experience: June, 1926, to June, 1928, assistant in civil engineering, Massachusetts Institute of Technology; October, 1927, to March, 1928, designer, carrying out least work analysis and deflection computations on Lake Champlain Bridge, for Fay, Spofford & Thorndike; June, 1928, to August, 1929, structural draftsman, designing, drawing, tracing and inspecting bridges for the Maine Central Railroad Company; August, 1929, to September, 1930, and June, 1931, to September, 1931, bridge designer and detailer, designing, and checking various structures, including a portion of the elevated express highway of the West Side Improvement for the New York Central Railroad Company; September, 1930, to date, instructor in civil engineering, teaching theory and design of structures, Massachusetts Institute of Technology; June, 1933, to date, designer, making economic studies, preliminary layouts and least work analysis of bridges over the Cape Cod Canal for Fay, Spofford & Thorndike. Refers to *J. B. Babcock, 3d, H. K. Barrows, C. B. Breed, F. H. Fay, C. M. Spofford*.

ADDITIONS

Member

STEPHEN HASELTINE, Jr., 32 Irving Street, Apartment 41, Cambridge.

Student

JOSEPH DEARBORN, 97 St. Stephen Street, Boston, Mass.

DEATHS

WILLIAM J. ALCOTT, Jr. October 20, 1933
J. WALDO SMITH . . . October 14, 1933

BOSTON SOCIETY OF CIVIL ENGINEERS

FOUNDED 1848

INDEX TO ADVERTISERS

	PAGE
ALGONQUIN ENGRAVING CO., INC., 18 Kingston St., Boston	iv
ASPINWALL & LINCOLN, 46 Cornhill, Boston	ii
BARBOUR, FRANK A., Tremont Building, Boston	iii
BARROWS, H. K., 6 Beacon St., Boston	ii
BLACK & BLUE PRINT CO., 71A Pearl St., Boston	vi
BLAKESLEE, ROLLINS CORPN., 79 Cambridge St., Boston	iii
BRUNO & PETITTI, CONTRACTORS, 18 Tremont St., Boston	iv
BRYANT, HENRY F., & SON, 334 Washington St., Brookline	iii
BUFF & BUFF CO., Jamaica Plain	v
CINDER CONCRETE UNITS CORPN., 201 Devonshire St., Boston	vi
COLEMAN BROS., 245 State St., Boston	iv.
CRANDALL ENGINEERING CO., 134 Main St., Cambridge	vi
ELLIS, W. H., & SON CO., East Boston	iv
FAY, SPOFFORD & THORNDIKE, 44 School St., Boston	ii
FULLER & MCCLINTOCK, 170 Broadway, New York	ii
GOW COMPANY INC., 956 Park Square Building, Boston	vi
HAWKRIDGE BROTHERS CO., 303 Congress St., Boston	iv
HOLZER, U., INC., 333 Washington St., Boston	iv
HUGHES, EDWARD F., 53 State St., Boston	v
HUTCHESON COMPANY, INC., 36 Bromfield St., Boston	v
JACKSON & MORELAND, Park Square Building, Boston	ii
KIMBALL CO., RICHARD D., 6 Beacon St., Boston	iii
MAIN, INC., CHAS. T., 201 Devonshire St., Boston	iii
MAKEPEACE, INC., B. L., 387 Washington St., Boston	Back cover
MANEY, C. J., CO., INC., 50 Congress St., Boston	v
METCALF & EDDY, Statler Building, Boston	ii
MILDHAM, HENRY C., 11 Beacon St., Boston	iii
MOORE, LEWIS E., 73 Tremont St., Boston	ii
NEW ENGLAND CONCRETE PIPE CORP., 100 Needham St., Newton	iii
NEW ENGLAND FOUNDATION CO., INC., 38 Chauncy St., Boston	iv
NEW ENGLAND POWER ENGINEERING & SERVICE CORPN., 89 Broad St., Boston	iv
NORTHERN STEEL COMPANY, 44 School St., Boston	iv
PACKARD, GEORGE A., 50 Congress St., Boston	iii
REIDY, MAURICE A., 44 School St., Boston	iii
RENDLE, ROY B., & CO., 322 Border St., East Boston	iv
SIMPSON BROS. CORPN., 77 Summer St., Boston	v
SKILLMAN & SUNDERLAND CO., 1042 Little Building, Boston	iv
SOMERSET PRINTING CO., 470 Atlantic Ave., Boston	iv
THOMPSON & LICHTNER, THE CO., INC., 702 Beacon St., Boston	ii
TOMASELLO, A. G., & SON, 250 Stuart St., Boston	v
TRIMOUNT DREDGING CO., 10 State St., Boston	iii
TURNER, HOWARD M., 12 Pearl St., Boston	ii
WESTON & SAMPSON, 14 Beacon St., Boston	ii
WHITMAN & HOWARD, 89 Broad St., Boston	ii
WORCESTER, J. R., & CO., 79 Milk St., Boston	ii
WRIGHT & POTTER PRINTING CO., 32 Derne St., Boston	v

Please mention the Journal when writing to Advertisers

LEWIS E. MOORE*Consulting Engineer*73 TREMONT STREET
BOSTON, MASS.**ASPINWALL & LINCOLN**

(WILLIAM S. CROCKER)

Civil Engineers

46 CORNHILL, BOSTON

FAY, SPOFFORD & THORNDIKE
Consulting EngineersInvestigations Reports Designs
Engineering Supervision Valuations
Port Developments Fire Prevention
Bridges Buildings Foundations
Water and Sewerage Systems

44 SCHOOL STREET BOSTON

FULLER & McCLINTOCK
EngineersGEORGE W. FULLER JAMES R. McCLINTOCK
F. G. CUNNINGHAM ELMER G. MANAHAN
C. A. EMERSON, JR. W. DONALDSON
E. W. WHITLOCKWater Supply, Water Purification, Sewerage,
Sewage Disposal, Garbage and Industrial
Wastes Problems, Valuation and Rate
Regulation of Public Utilities

NEW YORK -- 170 BROADWAY

H. K. BARROWS*Consulting Hydraulic Engineer*Water Power, Water Supply, Sewerage
Drainage. Investigations, Reports, Valua-
tions, Designs, Supervision of Construction

6 BEACON ST. BOSTON, MASS.

METCALF & EDDY
EngineersHarrison P. Eddy John P. Wentworth
Charles W. Sherman Harrison P. Eddy, Jr.
Almon L. Fales Arthur L. Shaw
Frank A. Marston E. Sherman ChaseWater, Sewage, Drainage, Garbage and
Industrial Wastes Problems

Valuations Laboratory

STATLER BUILDING BOSTON, MASS.

THE THOMPSON & LICHTNER CO., INC.BOSTON **Engineers** CHICAGODesigns and Engineering Supervision
Investigations, Testing and
Inspection of Structural Materials
Concrete Quality Control
Marketing and Production Service

Research Laboratory, 702 BEACON ST., BOSTON, MASS.

HOWARD M. TURNER*Consulting Engineer*Investigations, Valuations, Plans,
Supervision of Construction, Water
Power, Water Supply, Public Utility
and Industrial Properties

12 Pearl Street : : : Boston

WESTON & SAMPSON

ROBERT SPURR WESTON G. A. SAMPSON

Laboratory for the Analysis of Water,
Sewage, Filtering Materials, etc., Design,
Inspection and Supervision of Water Pur-
ification and Sewage Disposal Plants.

14 BEACON STREET, BOSTON, MASS.

WHITMAN & HOWARD**CIVIL ENGINEERS**

(EST. 1869. INC. 1924)

Investigations, Designs, Estimates, Reports
and Supervision in all Water Works, Sewerage,
Drainage, Waterfront Improvements and all
Municipal or Industrial Development Problems.

89 Broad Street Boston, Mass.

J. R. WORCESTER & CO.**Engineers**BUILDINGS BRIDGES FOUNDATIONS
STEEL AND REINFORCED CONCRETE
DESIGNS INVESTIGATIONS
EXPERT TESTIMONY
CEMENT AND SAND TESTING

79 MILK STREET BOSTON, MASS.

JACKSON & MORELAND**ENGINEERS**PUBLIC UTILITIES—INDUSTRIALS
RAILROAD ELECTRIFICATION
DESIGN AND SUPERVISION—VALUATIONS
ECONOMIC AND OPERATING REPORTS

BOSTON

NEW YORK

CHAS. T. MAIN, Inc.

ENGINEERS

201 DEVONSHIRE ST. -- BOSTON, MASS.

*Industrial Building Design — Steam
and Hydraulic Plants — Engineering
Consulting Engineering*

CHARLES T. MAIN
F. M. GUNBY
HARRY E. SAWTELL
W. F. UHL

CHARLES R. MAIN
A. W. BENOIT
MARCUS K. BRYAN
R. A. MONCRIEFF

H. F. BRYANT & SON

Consulting Engineers

CIVIL - ARCHITECTURAL - LANDSCAPE

334 WASHINGTON STREET

BROOKLINE

MAURICE A. REIDY

Consulting Engineer

STRUCTURAL DESIGNS FOUNDATIONS

44 SCHOOL STREET

BOSTON, MASS.

TRIMOUNT DREDGING COMPANY

10 STATE STREET

BOSTON

HERBERT T. GERRISH
PRESIDENT

Blakeslee Rollins Corporation

CONTRACTORS

79 Cambridge St. Boston, Mass.

Foundations of all kinds

Wharves and Dock Construction

D. A. BLAKESLEE, President
CLARENCE BLAKESLEE, Vice-President
J. W. ROLLINS, Vice-President and Treasurer
WALTER G. CHEEVER,
General Superintendent

Telephone, Lafayette 4869

RICHARD D. KIMBALL CO.

Consulting and Designing Engineers

Mechanical, Electrical and Sanitary

6 BEACON STREET
BOSTON, MASS.

FRANK A. BARBOUR

Consulting Engineer

*Water Supply, Water Purification
Sewerage and Sewage Disposal*

Tremont Building, Boston, Mass.

GEORGE A. PACKARD

**MINING . .
ENGINEER**

EXAMINATIONS AND REPORTS

*Supervision of Exploration, Purchase,
Development and Operation*

50 CONGRESS STREET, BOSTON

NEW ENGLAND CONCRETE PIPE CORP.

Manufacturers of

*Plain and Reinforced Concrete
Pipe for Sewers, Drains
and Culverts*

— Plants —

NEWTON and SPRINGFIELD (Feeding Hills), MASS.

HENRY C. MILDRAH

REAL ESTATE ENGINEER

**SURVEYS, PLANS, ESTIMATES
AND APPRAISALS**

FOR COURT CASES OF ALL KINDS

11 BEACON ST. -- BOSTON

*See Our***ARCHITECTURAL
STAINLESS STEEL***Exhibit At***ARCHITECTS EXHIBIT**

11 Beacon Street

HAWKRIDGE BROTHERS CO.

303 Congress Street, Boston

New England Foundation Co., Inc.*Engineering and Construction***Simplex Concrete Piles****Caissons — Difficult Foundations**

38 CHAUNCY STREET BOSTON, MASS.

COLEMAN BROS., Inc.**General Contractors and Builders**

Main Office

245 STATE STREET, BOSTON

HUBBARD 4880

NORTHERN STEEL COMPANY

44 SCHOOL STREET, BOSTON

Concrete Reinforcing Bars

— WORKS AT —

GLENWOOD STATION, MEDFORD, MASS.

*Compliments of**New England Power Engineering**& Service Corporation*

Telephone 0490 East Boston

ROY B. RENDLE & CO., Inc.**Pile Driving, Wharf and Bridge Building**

322 BORDER STREET

EAST BOSTON

ROY B. RENDLE, General Manager

**Dredging Pile Driving
Sea Wall and Bridge Building
Submerged Pipe and Foundations****W. H. ELLIS & SON COMPANY**

EAST BOSTON, MASSACHUSETTS

SKILLMAN & SUNDERLAND CO.

1042 LITTLE BUILDING, BOSTON, MASS.

*Representing***UNITED METAL PRODUCTS CO.**

CANTON, OHIO

*Manufacturers of***Hollow Metal Doors, Trim, Base, etc.****BRUNO & PETITTI**

CONTRACTORS

**WATERWORKS, SEWERS, HIGHWAYS AND
CONCRETE CONSTRUCTION**

18 Tremont Street

Boston, Mass.

Somerset Printing Co.**COMMERCIAL PRINTING**

ENGRAVING PLATE PRINTING

RELIEF PRINTING : EMBOSHING

470 ATLANTIC AVENUE, BOSTON

TELEPHONE - - - - - LIBERTY 3925

PHOTO ENGRAVERS

COLOR PLATES - HALF-TONES

LINE PLATES

ALGONQUIN

ENGRAVING CO. Inc.

18 Kingston Street, Boston, Mass.

Tel. HAN 4855

U. HOLZER, Inc.**BOOKBINDER**

333 Washington Street (Opp. Milk Street)

Or 24 Province Street Main Shop at Hyde Park

**Books Bound, Charts Mounted, Portfolios,
Lettering, Photographs Mounted**

Please mention the Journal when writing to Advertisers



TRANSITS AND LEVELS

*World Famous
for 71 Years*

GEORGE L. BUFF
LOUIS F. BUFF
HENRY A. BUFF
WILL J. BUFF
WILL J. BUFF, Jr.

BUFF PRECISION
is continuously in the
forefront



All Makes Repaired
at Reasonable Cost

Buff & Buff Co.

Jamaica Plain,
Mass.

C. J. MANEY CO., Inc. General Contractors

JOSEPH MANEY, *President*



50 CONGRESS STREET BOSTON

SIMPSON BROS. CORPORATION

Engineers and Contractors
for

Reinforced Concrete Construction

Asphalt, Concrete and Vulcanized
Pavements

A. G. TOMASELLO & SON, Inc. Contractors

*Steam Shovel Excavating, Foundations
and Public Works*

250 STUART STREET - BOSTON, MASS.
TELEPHONE HANCOCK 7270

JOS. A. TOMASELLO, Pres. and Treas.

Specialists on Reproduction
BLUE PRINTS, PHOTOSTAT PRINTS,
BLACK-LINE PRINTS, PLANOGRAPH PRINTS,
DRAWING SUPPLIES AND EQUIPMENT

HUTCHESON COMPANY, Inc.

36 BROMFIELD STREET, BOSTON

Tel. LIberty 1467-1468
Branch Exchange connecting All Departments

EDWARD F. HUGHES

Waterworks Contractor
Public and Private Water Supply
Artesian and Driven Wells

Foundation Borings

53 State St. Room 1102 Boston

Wright & Potter Printing Company

COMMERCIAL PRINTERS

32 Derne Street - Boston, Mass.

Tel. Capitol 2000, 2001, 2002

THE CRANDALL ENGINEERING COMPANY

CONSULTING AND
CONSTRUCTING ENGINEERS

DESIGN of Floating, Basin, and Railway Dry Docks,
Wharves, Piers, Bridges, etc.

CONSTRUCTION of these and other Engineering
Structures

134 MAIN STREET, CAMBRIDGE, MASS.

FOUNDATIONS

ENGINEERS AND CONTRACTORS

The Gow Company Inc.

956 Park Sq. Building
Boston

GOW CAISSONS
RAYMOND CONCRETE PILES
SOIL TEST BORINGS

90 WEST ST., NEW YORK CITY

111 W. MONROE ST., CHICAGO

REPRODUCTIONS

On Tracing Cloth or Paper by Gelatine Lithograph Process

BLUE PRINTS

BLACK & BLUE PRINT COMPANY

242 PURCHASE STREET, BOSTON

CINUCOR MASONRY UNITS

ARE LIGHT,
TOUGH AND
STRONG



Used where fire safety,
sound-proofness, and in-
sulation are essential.

CINDER CONCRETE UNITS CORPORATION, 201 Devonshire Street, Boston, Mass.

Please mention the Journal when writing to Advertisers

COMMITTEES

NOMINATING COMMITTEE

Past Presidents (Members of the Committee)

FRANK A. MARSTON

CHARLES B. BREED

FRANK E. WINSOR

W. W. BIGELOW
ERWIN HARSCH
W. D. HENDERSON
(Term expires March, 1934)

A. B. EDWARDS
FRANK L. FLOOD
LAWRENCE G. ROPES
(Term expires March, 1935)

SPECIAL COMMITTEES

Program

ARTHUR W. DEAN, *Chairman, ex officio*

CARROLL A. FARWELL
GLENNON GILBOY
FRANK W. GILCREAS
HOWARD A. GRAY
ALBERT HAERTLEIN

WILLIAM D. HENDERSON
LEROY M. HERSUM
SCOTT KEITH
CHARLES R. MAIN
CHARLES E. NICHOLS

KENNETH C. REYNOLDS
WALTER C. VOSS
FRANK B. WALKER
DANA M. WOOD

Publication

EVERETT N. HUTCHINS, *Chairman*

JOHN B. BABCOCK
J. STUART CRANDALL

GORDON M. FAIR
HOWARD M. TURNER

Library

ERWIN HARSCH, *Chairman*

HENRY B. ALVORD
EDWARD S. AVERELL

KIMBALL R. GARLAND
ARTHUR J. HARTY

C. FREDERICK JOY, JR.
EDWARD A. VARNEY

Subsoils of Boston

HARRY E. SAWTELL, *Chairman*

J. STUART CRANDALL
IRVING B. CROSBY

CARROLL A. FARWELL
CHARLES D. KIRKPATRICK

CHARLES W. ROBINSON
ALBERT C. TITCOMB

Social Activities

EDWARD S. AVERELL, *Chairman*

JOHN J. CAMPOBASSO
RICHARD H. HAMILL

JOHN H. HARDING
ARTHUR W. PETERSON

Membership and Publicity

A. B. EDWARDS, *Chairman*

EDWARD H. CAMERON
EDWARD I. GARDINER
JOHN F. GERMAINE

PAUL F. HOWARD
WALTER H. LEE

Relation of Sections to Main Society

JOHN B. BABCOCK, *Chairman*

GEORGE G. BOGREN
A. E. KLEINERT, JR.

ANTHONY TEDESCO
FREDERIC N. WEAVER

Registration and Licensing of Engineers

CHARLES B. BREED, *Chairman*

RICHARD K. HALE

FRANK E. WINSOR

Research

HARRY E. SAWTELL, *Chairman*

ARTHUR CASAGRANDE
RAYMOND W. COBURN

J. STUART CRANDALL
GORDON M. FAIR

FRANK A. MARSTON
FRANK B. WALKER

Run-off

ARTHUR T. SAFFORD, *Chairman*

HARRY P. BURDEN
ARTHUR C. EATON
X. HENRY GOODNOUGH
WILLIAM D. HENDERSON
RALPH W. HORNE

S. STANLEY KENT
H. B. KINNISON
R. R. MARSDEN
WILLIAM NOYES
L. B. PUFFER

CALEB MILLS SAVILLE
HOWARD M. TURNER
WILLIAM F. UHL
ARTHUR D. WESTON
FRANK E. WINSOR

Welfare

HAROLD K. BARROWS, *Chairman*

GEORGE G. BOGREN
RALPH W. HORNE

A. E. KLEINERT, JR.
ANTHONY TEDESCO

John R. Freeman Fund

CHARLES T. MAIN, *Chairman*

CHARLES M. ALLEN

ROBERT SPURR WESTON

HOWARD M. TURNER

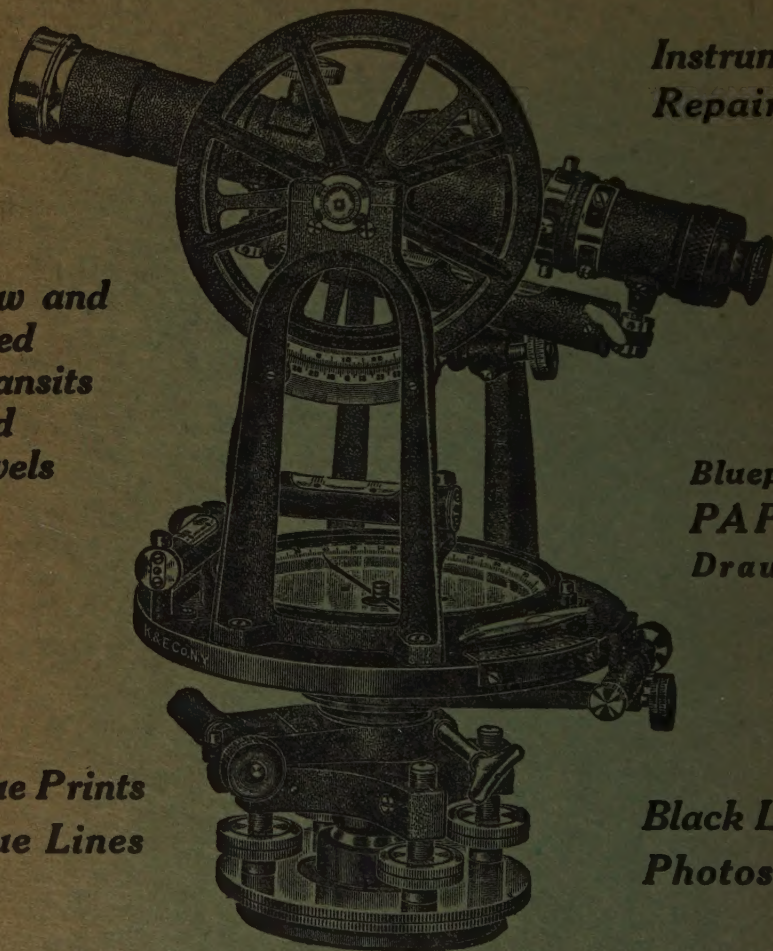
Desmond FitzGerald Award

ALBERT HAERTLEIN, *Chairman*

FRANK M. GUNBY

THOMAS R. CAMP

Field and Office Equipment and Supplies
FOR THE ENGINEER



*Instrument
Repairing*

*New and
Used
Transits
and
Levels*

*Blueprint
PAPER
Drawing*

*Blue Prints
Blue Lines*

*Black Lines
Photostats*

DRAFTING ROOM FURNITURE

B. L. MAKEPEACE, Inc.

387 WASHINGTON STREET, - 462 BOYLSTON STREET

Including H. H. SULLIVAN, INC., successors to FROST & ADAMS CO.,

BOSTON, MASS.